EFFECTS OF A 10 WEEK TRAINING PROGRAMME ON PHYSICAL PARAMETERS IN MALAYSIAN FOOTBALL REFEREES

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ABSTRACT

The objectives of this study were to investigate the effectiveness and acceptability of a 10 week training programme to improve the physical parameters namely repeated short sprints, repeated high intensity intermittent runs and aerobic power in Malaysian football referees. It also investigated whether there was a significant difference in the Sixty national football referees (purposive sampling) two training methods used. participated in this study. The participants were randomly assigned (fishbowl method) into three different groups namely Experimental Group 1, Experimental Group 2 and Control Group. Each group comprised of 20 participants. Experimental Group 1 strictly followed a 10 week training programme supervised by qualified trainers. They trained for three days in a week. Experimental Group 2 also reported for training three days a week at a different venue and trained using their own training programme. The design of this study focused upon the individual performances in physical parameters in the pre-test, providing training for 10 weeks and determining if the referees improved in the three variables using post-test results. A mixed between-within subject analysis known as split-plot ANOVA (SPANOVA) was used to test the objectives. The comparison of pre-test and post-tests results indicated that there was a statistical significant difference in performance of Experimental Group 1 in repeated short sprints t (19) =20.2, p<0.05. Repeated high intensity intermittent runs t (19) = 22.4, p<0.05. Aerobic power t (19) =19.4, p<0.05. There was also statistical significant difference in performance of Experimental Group 2 in repeated short sprints t (19) = 3.3, p<0.05. Repeated high intensity intermittent runs t (19) = 8.6, p<0.05. Aerobic power t (19) = 5.6, p<0.05. The results of Control Group indicated that there was a statistical significant difference in performance in repeated high intensity intermittent runs t (19) = 2.18, p<0.05. As for repeated short sprints and aerobic power there was no statistical significant difference. Repeated short sprints t (19) = 0.4, p>0.05. Aerobic power t (19) = 0.7, p>0.05. Further, the results indicated that there was a significance difference in the performance of the three groups in repeated short sprints after 10 weeks of training [F (2, 57) =154.75, p<0.05]. As for repeated high intensity intermittent runs, it was found that there was a significant difference in the performance of the three groups after 10 weeks. [F (2, 57) =75.86, p<.05]. Finally, as for aerobic power, the results showed that there was a significant difference in the performance of the three groups after 10 weeks.[F (2, 57) =141.18, p<.05]. The results of multiple comparisons among groups indicated that the performance of all the three groups differed from one another with Experimental Group 1 showing the best performance and the Control Group the poorest. The results provide meaningful support for the conclusion that a planned training programme is likely to be effective and acceptable to improve performance in repeated short sprints, repeated high intensity intermittent runs and aerobic power of football referees.

ABSTRAK

Tujuan kajian ini adalah untuk mengenalpasti keberkesanan dan penerimaan satu program latihan selama 10 minggu untuk mempertingkatkan parameter fizikal iaitu ulangan pecutan jarak dekat, ulangan larian intensiti tinggi dan kuasa aerobik pengadilpengadil bolasepak di Malaysia. Kajian ini juga adalah untuk mengetahui sama ada terdapat perbezaan ketara di antara dua kaedah latihan yang digunakan. Seramai 60 pengadil kebangsaan bolasepak (purposive sampling) mengambil bahagian di dalam kajian ini. Kesemua peserta-peserta diagihkan secara rawak (kaedah fishbowl) kepada tiga kumpulan iaitu Kumpulan Eksperimental 1, Kumpulan Eksperimental 2 dan Kumpulan Terkawal. Bilangan peserta dalam setiap kumpulan adalah 20 orang. Kumpulan Eksperimental 1 telah mengikuti program latihan yang disediakan selama 10 minggu, di bawah pengawasan jurulatih bertauliah. Peserta-peserta ini berlatih tiga hari dalam seminggu. Kumpulan Eksperimental 2 juga berlatih tetapi bersendirian tiga hari dalam seminggu di tempat yang berlainan dengan program latihan meraka sendiri.. Kajian ini memberi tumpuan kepada pencapaian individu dalam parameter fizikal di ujian pra, diberi latihan selama 10 minggu bagi mengetahui sama ada peserta dapat meningkatkan pencapaian dalam tiga pembolehubah akibat latihan yang dilaksanakan melalui ujian post. Split-plot ANOVA (SPANOVA) digunakan untuk menguji objektifobjektif. Perbandingan keputusan ujian pra dan ujian post menunjukkan terdapat perbezaan significan pencapaian Kumpulan Eksperimental 1 dalam ujian ulangan pecutan jarak dekat t (19) =20.2, p<0.05. Ulangan larian intensiti tinggi t (19) =22.4, p<0.05. Kuasa aerobik t (19) =19.4, p<0.05. Bagi Kumpulan Eksperimental 2, juga terdapat perbezaan significan dalam ujian pecutan jarak dekat t (19) = 3.3, p<0.05. Ulangan larian intensity tinggi t (19) =8.6, p<0.05. Kuasa aerobik t (19) =5.6, p<0.05. Keputusan bagi Kumpulan Terkawal menunjukkan terdapat perbezaan significan dalam ujian larian intersiti tinggi t (19) = 2.18, p<0.05. Bagi ujian pecutan jarak dekat dan

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kuasa aerobik tiada perbezaan significan. Ujian pecutan jarak dekat t (19) =0.4, p>0.05. Kuasa aerobic t (19) = 0.7, p>0.05. Keputusan yang diperolehi membuktikan terdapat perbezaan pencapaian di antara tiga kumpulan dalam aktiviti ulangan pecutan. [F (2, 57) =154.75, p<0.05]. Didapti juga perbezaan pencapaian di antara tiga kumpulan dalam aktiviti ulangan larian intensiti tinggi [F (2, 57) =75.86, p<.05]. Seterusnya, untuk juga terdapat perbezaan pencapaian di antara tiga kumpulan dalam kuasa aerobik [F (2, 57) =141.18, p<.05]. Keputusan pelbagai perbandingan antara kumpulan menunjukkan prestasi ketiga-tiga kumpulan adalah berbeza dan Kumpulan Eksperiental 1 menunjukkan prestasi terbaik manakala Kumpulan Terkawal menunjukkan pretasi terlemah. Keputusan kajian ini menyokong penuh program latihan sistematik yang dijalankan selama 10 minggu adalah sungguh berkesan dan boleh diterima untuk meningkatkan prestasi dalam aktiviti ulangan pecutan jarak dekat, ulangan larian intensiti tinggi dan kuasa aerobik bagi pengadil-pengadil bolasepak.

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CHAPTER 1: INTRODUCTION

This chapter explains the research domain of Malaysian football referees, followed by the justification for undertaking the research work. Justification explanation leads to the statement of problem, objectives, research questions and significance.

1.1 Introduction

The recognised international governing body of football is the Federation Internationale de Football Association (FIFA). FIFA headquarters is located in Zurich. According to a survey conducted by FIFA published in 2006, over 230 million people from more than 200 countries regularly play football. It was also reported that football has the highest global television audience in sport (FIFA Big Count, 2006). FIFA (2011) announced that 208 men's national football associations are affiliated to FIFA. National Associations oversee football matches within individual countries.

In many parts of the world, football evokes great passions and plays an important role in the life of individual fans, local communities and even nations. Stormer & Neil (2006) reported that the Ivory Coast national football team helped secure a truce to the nation's civil war.

Austin & Merrill (2007) supported the view and stated that the match helped further reduce tensions between government and rebel forces by playing a match in the rebel capital of Bouake, an occasion that brought both armies together peacefully for the first time.

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Today, football is played at a professional level all over the world. Millions of people regularly go to football stadiums to follow their favourite teams stated Ingle, Sean Glendenning & Barry (2003). FIFA (2003) announced that billions more watch the game on television or on the internet and a large number of people also play football at an amateur level.

The major international competition in football is the World Cup, organized by FIFA. This competition takes place over a four-year period. More than 190 national teams compete in qualifying tournaments within the scope of continental confederations for a place in the finals. The finals tournament, the 2010 FIFA World Cup was held in South Africa from June 11 to July 11 (The FIFA Calendar, 2010). An official survey (FIFA Big Count 2006) revealed that there were more than 840,000 registered referees and assistant referees worldwide. Wherever the game is played, referees are needed to supervise the matches.

Football is a sport with global appeal. Referees have the tasks of implementing the laws of the game within the context of the game. The decisions made by the referees are final. Quality refereeing provides players with a chance to display a high level of skills and tactics. It ensures smooth flow of play and this brings about satisfaction and enjoyment to the fans.

Thus, the attributes of quality refereeing ensures that it is a challenging, exciting and rewarding task. On the other hand, poor refereeing creates anxiety, frustration, anger and eventually some negative physical behaviour by players who perceived that they had been unfairly judged. When this happens, the referees feel frustrated, abused and unappreciated. . In fact, it is fair to say that, without referees, the world's most popular game could not go ahead at all (Lategan, 2011). During a football match the referee covers a distance of between 7000 and 10000 metres at an average heart rate of 150 to 160 beats per minute and an average oxygen uptake of approximately 80% of the maximum aerobic power (Castagna, Abt & D'Ottavio, 2004; D'Ottavio & Castagna, 2001).

The activity profile and physical demands of football refereeing have been examined in a number of studies (Castagna, Abt & D'Ottavio 2004; Da Silva & Fernandez 2003; Helson & Bultynck 2004; Weston et al., 2006). It was observed that the referees had a significant aerobic power production throughout the match and episodes of considerable anaerobic energy turnover. Further, it was found that the ability to perform high intensity running was reduced towards the end of a match. The studies also reported that referees were far away from play and infringements towards the end of match play, thereby indicating accumulated fatigue.

In an attempt to overcome the problem, FIFA in 2004 announced that The Helsen Test also known FIFA Fitness Test be used to test the fitness of referees. The components of FIFA Fitness Test were Repeated Short Sprint Test, Repeated High Intensity Intermittent Test and Cooper's 12 minute test. These tests would be conducted on a 400 metre athletic track.

The requirements set by FIFA to pass the repeated short sprints test is six sprints, twenty repetitions of 150 metres in repeated high intensity intermittent test and complete a distance of 2.6 kilometres in the Cooper 12 minute test. If the referees achieved all the requirements, their fitness will be deemed sufficient to cope with match demands.

FIFA (2005) selected 48 referees and assistant referees to officiate FIFA World Youth Championship at Netherlands and these officials would feature in 2006 World Cup if they passed the FIFA Fitness Test. Thirteen referees and assistant referees were ordered to return home before the world's top U-20 kicked off as they failed the fitness test. It was sad to note that two Malaysian referees were among the 13 who were sent back.

Julu & Johnson (2007) reported that Liberian FIFA referee Patrick WhityPaye who was selected by FIFA to officiate the African Youth Championship Tournament in Congo failed to pass The FIFA Fitness Test and therefore not eligible to officiate in that championship.

Nathambeleni Gabara (2010) reported that it was shocking to hear that two of the thirty referee trios selected to officiate at the FIFA World Cup South Africa 2010 failed FIFA Fitness Test and therefore had to be substituted.

FIFA Physical Instructor, Mark Mzengo announced that Zimbabwe's top referees embarrassed the nation when they failed FIFA fitness test putting a dent on the chances of the country retaining their full quota of 10 match officials on FIFA list in 2011. The results showed that only two referees were able to pass the FIFA fitness test. Mzengo felt that the referees needed to train training seriously.

Tiadi Blair, the trainer of Guyana Football Association reported that 17 of 37 referees failed The FIFA Fitness Test held on September, 2010. He stated that the referees were not taking the fitness aspects seriously. He hoped that the referees should train harder and more intensely with an organized training programme.

It was noted that many top referees who were registered with FIFA were unable to pass the FIFA Fitness Test when they were tested before the start of a tournament. Therefore, FIFA directed all its national affiliates to register only referees who were physically fit and in good training.

FIFA (2010) stressed that for registration of referees for the year 2012, the proposed referees must have passed the appropriate FIFA Fitness Test. Referees who did not pass the test would not be accepted for registration. The tests would be conducted by a panel of independent testers nominated by FIFA to ensure validity and reliability.

The Football Association of Malaysia (FAM) selected 65 top referees in Malaysia to run the FIFA fitness test at Shah Alam Stadium in July, 2012. The test started at 7.30 am. The results showed that 20 referees failed the tests and therefore not eligible to supervise local or international matches. FAM felt there was an urgent need to set up a committee to investigate the reasons why a number of top referees in Malaysia failed the test.

The results of investigation showed that the referees who failed the test were proficient in game knowledge, decision making skills, psychological skills, strategic skills, control of the game but lacked physical fitness. It was found that these referees failed because they did not have professional trainers or an effective training programme. The referees have to make time outside their day jobs to stay in top physical condition and since refereeing is not a full time job, the payment received was not satisfactory. It was found that the main reason why these referees failed was because they were not physically prepared with an effective training programme. However, FAM (2012) felt that with the implementation of a proper training schedule with professional trainers, a more satisfactory performance could be achieved. Five members were appointed to formulate a 10 Week High Intensity Interval Training (HIIT) programme for the referees in Malaysia. A number of studies supported the concept of providing training for referees to improve performance.

A study by Helgerud et al. (2001) showed that HIIT is an effective training strategy for improving the aerobic fitness, power, or sprint performance of football referees. Their results have been confirmed by Impellizzeri et al. (2008); McMillan et al. (2005) who have shown that HIIT, using both specific and generic exercises is equally effective in enhancing aerobic and anaerobic fitness of football. Therefore, HIIT can be considered an effective training strategy for aerobic, anaerobic and sprint development in football referees.

Studies by Bugomaster et al. (2005); Dawson et al. (1998); MacDougall et al. (1998) & Ortenblad, (2000) have shown that HIIT consisting of maximal or nearmaximal short-term efforts (5 to 30 seconds) can produce improvements in the ability to repeat several sets of anaerobic exercise. They further reported that HIIT can also be effective in enhancing VO₂max and aerobic enzyme activity. These investigations support the effectiveness of HIIT for enhancing both the aerobic and anaerobic capacities. The study by Gambetta (2007) indicated that significant improvement in speed and aerobic power in football referees occurred when they trained three days per week in 10 weeks. He reported that there was no significant difference in improvement between subjects who exercised three consecutive days per week or subjects who exercised every alternate day.

Daussin et al. (2007) measured the increase in VO₂max among subjects who performed 10 weeks of either HIIT programme or a continuous aerobic endurance exercise programme. It was found that the increase in VO₂max was significantly higher in the HIIT programme (15%) compared to the continuous aerobic endurance group (9%).

Helgerud et al. (2007) stated that four repetitions of 4 minute runs at 90% – 95% of heart rate, followed by three minutes of active recovery, performed three days per week for 10 weeks resulted in a 10% greater improvement in stroke volume compared to long, slow distance training three days per week for 10 weeks. He further stated that stroke volume is one of the key components of the body's ability to deliver maximum oxygen to working muscles.

Match analysis studies by Spencer et al. (2005) have also demonstrated that football referees are required to repeatedly produce maximal or near maximal actions of short duration with brief recovery periods. They further stated that for these reasons, football referees training should commonly include physical activities aimed to enhance both aerobic and anaerobic power. These activities result in metabolic responses similar to those which occur during actual matches. (Rampinini et al., 2007; Spencer et al., 2005) The results of studies (Castagna, Abt & D'Ottavio, 2002; Castagna & D'Ottavio, 2001; Krustrup & Bangsbo, 2001) indicated that referees with higher aerobic power run further and fitter referees are able to remain closer to play. They further reported that the same physiological responses will apply to most other field-based team sports when aerobic power is increased.

Bangsbo, Norregaard & Thorso (1991); Mohr, Krustrup & Bangsbo (2003); Weston et al. (2007) reported that football is a physically demanding sport requiring the repetition of many diverse activities such as jogging, running and sprinting. They further stated that improvement in aerobic power and sprints is dependent on intensity, duration and frequency of training.

The studies indicated that significant improvement in speed and aerobic power could be achieved using a HIIT programme with a frequency of three days per week over a period of eight to ten weeks. Based on the research findings, FAM with the help of expertise prepared a 10 week training programme with duration of three hourly sessions a week for the football referees of Malaysia

1.2 Statement of Problem

Guillen & Feltz (2011) reported that to be a successful referee, it is important to be proficient in the following areas: game knowledge, decision-makings skills, psychological skills, strategic skills, communication or control of the game, aerobic power and speed. The investigation by FAM showed that the Malaysian referees are proficient in the areas mentioned above but lacked aerobic power and speed and as a result unable to pass the FIFA Fitness Test.

Referees are required to do FIFA Fitness Tests at a short notice before a tournament. It will certainly be embarrassing to get an appointment and have to return home because the referee failed the fitness tests. Getting an appointment and failing to fulfil it because of lack of fitness could very well mean that the referee may never get another opportunity. Referees who are fit and remain fit are bound to be presented with opportunities.

Therefore, the objectives of the study are to investigate the effectiveness of a 10 Week HIIT programme on the physical parameters comprising of repeated short sprints, repeated high intensity intermittent runs and aerobic power in Malaysian Football Referees.

1.3 Statement of Objectives

This research aims at investigating the effectiveness of a 10 Week Training Programme on the physical parameters comprising of repeated short sprints, repeated high intensity intermittent runs and aerobic power in Malaysian Football Referees. The main objectives of the study are as follows:

- 1.3.1 To investigate whether there is a significant difference in the performance of Experimental Group 1 in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results.
- 1.3.2 To investigate whether there is a significant difference in the performance of Experimental Group 2 in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results.
- 1.3.4 To investigate whether there is a significant difference in the performance of Control Group in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results.
- 1.3.5 To compare the significance of a 10 Week HIIT Programme on repeated short sprints, repeated high intensity intermittent runs and aerobic power among the three groups of football referees.

1.4 Research Questions

- 1.4.1 Is there a statistical significant difference in the performance of Experimental Group 1 in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results?
- 1.4.2 Is there a statistical significant difference in the performance of Experimental Group 2 in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results?
- 1.4.3 Is there a statistical significant difference in the performance of Control Group in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results?
- 1.4.4 Is there a statistical significant difference in the performances of the three groups in repeated short sprints after participating in a 10 Week Training Programme?
- 1.4.5 Is there a statistical significant difference in the performances of the three groups in repeated high intensity intermittent runs after participating in a 10 Week Training Programme?
- 1.4.6 Is there a statistical significant difference in the performances of the three groups in aerobic power after participating in a 10 Week Training Programme?

1.5. Significance of the Study

Football has become more athletic and faster in recent years and the referee can no longer remain outside these developments. Given the high physical load imposed on top-class referees during actual match play, fitness levels need to be sufficient enough for the referees to be able to cope with the demands of their games through keeping up with play at all times (D'Ottavio & Castagna, 2001; Helson & Bultynck, 2004).

As a result, FIFA in 2008 made it compulsory for all international referees to pass the FIFA Fitness Test if they desired to be registered as FIFA referees. Minimum requirements have been set by FIFA so that should the referees achieve this standard, their fitness is deemed sufficient to cope with match demands. The FIFA Fitness Test is performed prior to registration as FIFA referees and before an official tournament organised by FIFA. All FIFA referees must pass the tests.

However, when combined with the fact that referees are on average 10 to 15 years older than their playing counterparts and aging has a negative effect on fitness levels. Referees have to work extremely hard in training to ensure that they attain, and maintain an appropriate level fitness. In most countries referees work full-time and their physical training sessions often have to be arranged around work and family commitments.

Football referees are often left on their own to develop their physical fitness efficiency. If they fail the FIFA Fitness Test, they are not allowed to officiate in a particular tournament. There has been no specific training programme designed to improve the fitness of football referees in Malaysia.

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Therefore, in order to ensure football referees can attain an optimal level of fitness, emphasis within their fitness preparation programmes has to be firmly placed upon quality structured training sessions that provide an appropriate training stimulus to enable the attainment of such fitness. The ability to perform high intensity exercise along with good repeated sprint ability is a vital physiological attribute for football referees.

Consequently, the training programmes which referees follow on a weekly basis should have a structured blend of high intensity interval training sessions, complemented with sprint training sessions dedicated towards the improvement of speed and endurance (Helson & Bultynck, 2004).

Hence, this study has been designed to investigate the effectiveness and acceptability of a 10 Week HIIT programme to improve repeated short sprints, repeated high intensity intermittent runs and aerobic power of referees in Malaysia.

The findings of this study will provide significant feedback on the effectiveness of a 10 week training programme for football referees. This study will evaluate whether a 10 Week HIIT programme could be adopted as a formal training programme for football referees. This training programme identified in this study might contribute significantly towards improving repeated short sprints, capacity to perform repeated high intensity intermittent runs and improve aerobic power of football referees After undergoing 10 weeks of HIIT, the referees would be able to know whether they could pass the FIFA Fitness Test. If they could, an achievement of this status would definitely be a strong motivating factor for these referees and also to all aspiring football referees.

1.6 Limitations of the Study

This study, which involves the measurement of repeated short sprints, repeated high intensity intermittent runs and aerobic power of football referees in Malaysia is limited to the following conditions:

- 1.6.1 Sixty part-time referees registered for the year 2013 with the Football Association of Selangor (FAS) and Football Association of Kuala Lumpur (KLFA)
- 1.6.2 Referees who were born between January 1, 1972 and December 31, 1986
- 1.6.3 Referees who officiated in the FAS and KLFA football league matches in 2013.
- 1.6.4 Referees who resided in Kuala Lumpur and Selangor.
- 1.6.5 Referees who passed the medical examination conducted by a qualified medical doctor

- 1.6.6 Referees who were not handicapped or having any form of abnormalities.
- 1.6.7 The FIFA Fitness Tests and Cooper's 12 minute run employed.

1.7 Operational Definition

The following terms may be understood within the context of this study.

1.7.1 Referees

National referees registered with Football Association of Malaysia. They must be active referees officiating football matches at state level in 2013. They must possess medical fitness certificates.

1.7.2 Participants around Kuala Lumpur

The participants are football referees who resided in Kuala Lumpur and Selangor.

1.7.3 Football League Matches

The matches organized by FAS or KLFA in 2013 and the teams must be registered with the Football Associations.

1.7.4 FIFA Fitness Test

The components of FIFA Fitness Test were Repeated Short Sprint Test, Repeated High Intensity Intermittent Runs and Coopers 12 minute run tested on a 400 metre track.

1.7.5 HIIT Programmes

Training programme of duration 60 minutes per session and carried out three sessions per week for a period of 10 weeks.

1.7.6 Physical Parameters

Repeated short sprints, repeated high intensity intermittent runs and aerobic power.

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CHAPTER 2: REVIEW OF LITERATURE

There exists an abundance of literature related to repeated short sprints, repeated high intensity intermittent runs and aerobic power in football referees. However, for the purpose of this study, the review of literature is limited to cover very specific areas related to the following headings:-

- 2.1 Movement patterns and distance covered by referees in a football match.
- 2.2 Energy expenditure and physiological responses of referees during a match.
- 2.3 High Intensity Interval Training (HIIT) characteristics and its effects.
- 2.4 HIIT and physiological responses to cardiovascular and respiratory system.
- 2.5 HIIT and physiological adaptations in the muscular and metabolic system
- 2.6. Metabolic adaptations to Sprint training (ST).

2.1 Movement patterns and distance covered by referees in a football match.

Castagna et al. (2004); Catterall et al. (1993); D'Ottavio & Castagna (2001); Johnston & McNaughton (1994) & Harley et al. (2002) stated that the work-rate of referees during matches could be determined by motion analysis using procedures that have been adopted for monitoring players. The movement patterns of referees include low-intensity activities, high-intensity activities and bouts of movements like running backwards or shuffling sideways.

The distance covered by football referees is characterized by low, medium and high intensities and activities include sprinting, running backwards and sideways Castagna et al. (2007). Previous studies by Castagna et al. (2004); D'Ottavio & Castagna (2001); Harley et al. (2002); Krustrup & Bangsbo (2001; Krustrup et al. (2002) reported that the referees performed about 50% of the distance walking and jogging at low intensity. Standing still accounted for 11-22% of the match duration. About 39% of the total distance covered comprised of medium and high intensity activities. Backward running was reported 11% of the total distance covered (Castagna et al., 2007).

Harley et al. (2002) found the distances covered in a match by the referees ranged from 7-11 kilometres. Castagna et al. (2007) reported the distance covered by Italian referees officiating in Italian first division championship ranged from 7-12 kilometres. Observations on referees in the English, Danish and Tasmanian leagues indicated that referees cover between 9 and 13 kilometres in a game. The highest distance recorded was 13.1 kilometres in the Italian League (D'Ottavio & Castagna, 2001) and 11.1 kilometres in the Danish League (Krustrup & Bangsbo, 2001). Table 2.1 indicates the distances covered by referees in a football match.

Table 2.1

Competition	n	Age	Distance Covered (metres)	Reference
English Premier League & First Division	14	-	9438 ± 707	Catterall et al. (1993)
Tasmanian State League	10	38.1 ± 3.8	9408 ± 838	Johnston & McNaughton (1994)
Italian Serie A	18	37.5 ± 2.1	11376 ± 1604	D'Ottavio & Castagna (2001)
	13	37.0 ± 3.0	12956 ± 548	Castagna et al.(2004)
Danish Superliga & First Division	27	38.0 (29-47)	10070 ± 130	Krustrup & Bangsbo (2001)
European Cup Matches	13	38.0 ± 3.0	11218 ± 1056	Castagna et al.(2004)

Distance covered by referees during football matches. Values are m ± SD

The results of studies on movement patterns of Danish referees by Krustrup & Bangsbo (2001) are indicated in Figure 2.1. The majority of movement patterns were executed at low intensity walking and jogging and time spent standing amounted to 21.8%.



Figure 2.1: The percent of total time occupied by different categories of activity in Top-Class Danish referees. The diagram is drawn from data Krustrup & Bangsbo (2001)

Helson & Bultynck (2004), Rebelo et al. (2002) reported that referees were involved in walking and jogging movements 41.8% to 73.8 % during match coverage. Sprinting and high speed running were performed 4% to 18%. There was a significant reduction of sprinting and high speed running during the second half. The results indicated that the reason for the decline in sprinting was fatigue towards the end of the match. Krustrup & Bangsbo (2001) operating on a time-base and combining highintensity running and sprinting found that on average the referees performed 161 runs with a mean duration of 2.3 seconds during a game. Further it was reported that the Danish referees were found to spend significantly more time standing and less time engaged in high-speed running and sprinting in the second half compared with the first half. Similarly, Catterall et al. (1993) reported a significant decline in the distance covered by English referees during the second half. Castagna et al. (2004) indicated that Italian referees covered less distance running backwards and sideways in the second half as compared to the first half, no differences being observed in the other movement categories.

When a comparison is made on the total distance covered between the two halves of a match, conflicting results had been reported. Castagna et al. (2004); Catterall et al. (1993); D'Ottavio & Castagna, (2001); Johnston & McNaughton, (1994); Krustrup & Bangsbo (2001). The result of studies by Catterall et al. (1993) and D'Ottavio & Castagna (2001) showed a significant decrease in distance covered in the second 45 minutes. In lower leagues, an even greater decrement in the second half was documented (Harley et al., 2002). Castagna et al. (2004) indicated that Italian referees covered less distance running backwards and sideways in the second half as compared to the first half, no differences being observed in the other movement categories.

However, other researchers found no difference between halves in national referees Johnston & McNaughton (1994); Krustrup & Bangsbo (2001) and international referees Castagna et al. (2004). The referees adopt pacing strategies in order to conserve energy during the match (Castagna et al., 2007).

Krustrup & Bangsbo (2001) stated that the decline in performance during the second half has been linked to a decrease of muscle glycogen stores. This causes fatigue and is associated with a drop in work rate of referees. The referees were further away from infringements in the second half due to fatigue. The referees had to follow movements of the ball and must be prepared for direct methods of attacking play towards the end of the game. The distance covered at high intensity decreased in the second half.

2.2 Energy expenditure and physiological responses of referees during a match

The energy needs for an individual varies according to their age, sex and the physical activities performed. (National Research Council, 1996); however, football referees' energy demand oscillates from 3500 to 4300 kcal/day. It should be acknowledged that these values for referees vary and energy expenditure depends on the frequency and intensity of football matches (Bangsbo et al., 2006; Clark 1994; Ebine et al., 2002; Rico-Sanz (1998a).

Research by Drust et al. (2007) addressed the metabolic demands imposed on football referees during competitive and friendly matches. The results demonstrated, that the majority of the body's physiological systems are stressed during the course of a football game. These include metabolic energy systems, the musculoskeletal system and perhaps also the nervous and immune system. It was widely documented that the referees had to sustain a high rate of work for a period of at least 90 minutes.

It was further reported that football refereeing is characterised by high-intensity anaerobic efforts superimposed on a background of aerobic activity. This varying intensity places high metabolic demands on the energy delivery pathways. In this high intensity intermittent sport, many other factors such as speed, power, strength, agility, flexibility and anaerobic capacity all combine with aerobic capacity also contribute to a successful game (Drust et al., 2007).

From the metabolic point of view, football is classified as an alternating aerobic and anaerobic engagement sport. During intermittent exercise, well-trained referees regularly make use of the system of oxygen transport without creating high lactate levels in the muscles and in the blood. Motion analyses of football matches demonstrated that referees covered 10-12 kilometres during a match lasting 90 minutes, involving a combination of high intensity sprinting, prolonged running at more moderate speeds and periods of walking (Tumilty, 1993).

Castagna et al. (2004); Catterall et al. (1993); Da Silva & Rodriguez-Añez, (1999); Johnston & McNaughton, (1994); Krustrup & Bangsbo, (2001) observed that during officials matches football referees performed physical activities of low and moderate intensity resulting in a significant decline in energy expenditure between the first and second half. Their studies involving football referees also confirmed that the physical activity of referees during match-play predominantly involves the utilization of energy originating from aerobic and anaerobic metabolism.

Bangsbo (1994) reported that referees had significant aerobic energy expenditure throughout a match and episodes of considerable anaerobic energy turnover. The aerobic energy production accounted for approximately 90% of total energy consumption. This percentage present a large inter-individual differences due to the variety of factors which influence exercise intensity. Castagna et al. (2002) acknowledged that all the evidence presented in the studies supported the necessity of improving aerobic and anaerobic metabolism in football referees. Several studies indicated that more energy is used for running backwards than forward running Flynn et al. (1994); Williford et al. (1998). Factors such as depletion of glycogen stores, dehydration and hyperthermia may contribute to the development of fatigue in the later stages of a football game. (Bangsbo et al., 2006; Castagna et al., 2007; Da Silva & Fernandez, 2003; Reilly, 1997).

Energy expenditure can be measured directly in laboratory or estimated indirectly from oxygen uptake. Several reports have shown that it is possible to estimate the energy expenditure of a physical activity with reasonable precision using the consumption of oxygen (Daniels & Daniels, 1992).

Indirect measurements are generally used to estimate energy expenditure during football matches Bangsbo et al. (2006). The measures of heart-rate were utilized in several studies to estimate exercise intensity and aerobic involvements of football referees (Bangsbo et al., 2006; Castagna, 2007). Factors like dehydration, hyperthermia and mental stress elevate the heart rate without affecting oxygen uptake, leading to an over-estimation of this variable. The energy expenditure was significantly reduced in the second half. A fact that could be explained by the reduction in jogging and backward running observed in this period (Shephard, 1992).

In attempting to quantify the aerobic demands of football refereeing, heart rate (HR) monitoring and measurements of $VO_{2 max}$ have been made Catterall et al. (1993); D'Ottavio & Castagna, (2001); Johnston & McNaughton, (1994); Krustrup & Bangsbo (2001); Weston & Brewer (2002). These studies show that a referee may reach between 85% of his maximal HR (Johnston & McNaughton, 1994) and 95% of his maximal HR (Catterall et al., 1993) during a football game. Helsen & Bultynck (2004) reported an average of 85% maximal HR.
The estimated match VO₂ uptake, calculated from the HR-VO₂ curve has been found to be approximately 80-81% of the VO_{2 max} (assessed in the laboratory setting) (Weston & Brewer 2002). Further, looking at the differences between the two halves, it was found lower HR and lower estimated percentages of VO_{2 max} in the second 45 minutes of the match (D'Ottavio & Castagna, 2001; Krustrup & Bangsbo, 2001). Using portable gas analyzers the aerobic match demands in Italian referees during friendly matches, was found the oxygen uptake was 68% of the individual VO_{2 max}. The researchers found that a significantly higher oxygen uptake (74 % of VO_{2 max}) than with the HR-VO₂ estimation method. Although the accuracy of "directly measured" values of oxygen consumption is also the subject of some debate (due to the potential of portable gas analysis systems to hinder movement and hence influence motor behaviour) researchers nonetheless advise caution when interpreting the results obtained by estimation from HR-VO₂ data collected in the laboratory setting. It was probably safe to conclude that the average oxygen uptake during the match is in the region of 70% VO₂ max (D'Ottavio & Castagna, 2002).

Krustrup & Bangsbo (2001) used the relationship between heart rate and oxygen uptake to estimate the oxygen consumption during a match. Oxygen uptake showed 3.03 litres per minute which corresponded to 81 % of VO_{2max} . Elite referees had appreciable aerobic energy expenditure during match-play. Evaluation of the variation in heart rate during competition provides useful information when attempting to determine the referee's physiological responses to match-play.

Blood lactate concentrations measured during a match provided an in-depth insight of the involvement of anaerobic energy provision. Mean blood lactate concentration had been recorded as 4.8 (2.0 - 9.8) and 5.1(2.3 - 14.0) mmol×l-1 at the end of the first and second half (Krustrup & Bansgbo, 2001).

Stolen et al. (2005) indicated that there is some debate as to whether $VO_{2 max}$ is a sensitive measure of performance capacity in football. Castagna & D'Ottavio (2001) showed that, in Italian referees, $VO_{2 max}$ determined both the total distance covered and the exercise intensity during a game. The referees who possessed a higher $VO_{2 max}$ were shown to be more active during the course of the second half compared with their less well-trained counterparts.

Match performance and match physiological responses of referees are shown in Table 2.2. The sequence of alternating attacking situations obliges the referee to constantly move between the attack and defence zones, in order to keep up with the game. Different studies report different distances covered by the referee during a match. There are many reasons why this figure might vary between studies (country, level of competition, team/players' behavior, refereeing strategies, aerobic fitness level) (Castagna et al., 2007).

Table 2.2

VO_{2 max}, match performance and match physiological responses in male football referees (Stolen et al., 2005).

$VO_{2 max}$, Match Performance and Physiological Responses		Referees
$VO_{2 max} (mL.kg^{-1}.min^{-1})$		41 – 56
Distance Covered		9 – 14 km
Distance Covered		11.4 km
Match Activities	Activity Changes (number)	965-1577
	Activity Changes (time between)	4 sec
	High Intensity Activity (Sprinting) (% of distance covered)	2-12%
	High Intensity Running (ProZone*)	1.1 km
Aerobic Demands	Average Work Intensity	85-95% of HR HR_m
	Match Oxygen Uptake 1 (Indirect Measure)	Approximately 80% VO _{2 max}
	Match Oxygen Uptake 2 (Direct Measure)	Approximately 68% VO _{2max}
Blood Lactate	End of 1 st Half	Approximately 4.8 mmol/L
	End of 2 nd Half	Approximately 5.1 mmol/L

The different methods of measurement (motion analysis systems) also play a role in this context Carling et al. (2008). The Premier League adopted a valid/reliable computerised, semi-automatic video match analysis image recognition system for the monitoring of referees performances during official matches (Di Salvo et al. 2009; Weston et al., 2008). Data from the season 2008-2009, Weston (2009) reported the activity profile of referees. Since the games became faster in recent years, the number of activities during a match increased for referees (Krustrup & Bangsbo, 2001).

The referees cover more than 50% of the total distance moving at a low intensity but they also need to perform a considerable amount of medium-intensity and highintensity activities, in order to keep up with the tempo of the game. For this reason, elite refereeing is considered a highly intermittent exercise mode. Referees usually run backwards (studies show distances ranging from seven to 18% of the whole distance) when taking off from a game action while still controlling it. Directional modes, backward and sideways running, are physically demanding and represent additional energy expenditure for the match officials (Castagna et al., 2007).

2.3 High Intensity Interval Training (HIIT) characteristics and its effects.

Interval training was first used in 1930 by a German professor of physical education, Dr. Woldemar Gerschler and Dr. Herbert Reindell, a cardiologist. They developed a system of running intense, short distances followed by brief recovery intervals. He reported that interval training protocol was credited for several record breaking performances in the 400, 800, 1500 and 5000 metre running events. Interval training has since been used extensively with athletes participating in sports that require energy contribution from both the aerobic and anaerobic systems (Sears, 2011).

HIIT is also referred to as sprint interval training (SIT) and high intensity intermittent training. HIIT began to emerge in the 1960s in Sweden. Physiologists demonstrated how manipulation of work and rest durations could dramatically impact physiological changes to intermittent exercise (Seiler et al., 2007).

Gibala & Mc Gee (2008) stated that HIIT is a form of training that has been widely used in sport to develop physical fitness, induce physiological adaptations and improve sports performance. HIIT is a method that is characterised by brief intermittent bursts of vigorous activity, interspersed by periods of rest or low intensity exercise.

HIIT is a variant of interval training that consists of repeated high intensity work intervals done at or near maximal oxygen uptake followed by short, lower intensity recovery intervals. HIIT is frequently used in endurance sports as a way of increasing aerobic capacity and improving overall athletic performance. The programme uses the principle of overload to stress physiological systems beyond regular training intensities can be effectively used in any setting in which exercise intensity can be manipulated quickly (Manna, Khanna & Dhara, 2009)

According to Perry et al. (2008), HIIT is a form of interval training, an exercise strategy alternating short periods of intense anaerobic exercise with recovery periods. Further, it was stated that usual HIIT sessions may vary from four to thirty minutes. These short, intense workouts improve glucose metabolism and fat burning but may not be as effective for improving muscle and bone mass. HIIT leads to rapid improvement in $VO_{2 max}$ and endurance performance.

HIIT is characterized by work bouts interspersed by recovery periods (Eliot, 1999 & Hargreaves, 1995). It involves the manipulation of intensity and duration of work to rest ratios where the resting periods allow the individual to rest and recover between sets (Wilmore & Costill, 1994). A comparison on the effectiveness of HIIT and traditional endurance training methods were explored. The results of studies concluded that HIIT tax both the anaerobic and aerobic energy releasing systems almost maximally (Tabata et al., 1996).

Kokkins (2012) reported HIIT stresses the physiological systems of the body to a greater extent than continuous training, because the sprint bouts are done at intensities that are higher than the anaerobic threshold. The work done usually elicits approximately 85-95% HR $_{max}$ and rest intervals can either be passive or active.

2.4 HIIT and physiological responses to cardiovascular and respiratory system.

According to Wilmore & Costill (1994) when challenged with any physical task, the human body responds through a series of integrated changes in function of its physiological systems. Movement requires activation and control of the musculoskeletal system; the cardiovascular and respiratory systems provide the ability to sustain this movement over extended periods. When the body engages in physical training several times a week or more frequently, each of these physiological systems undergoes specific adaptations that increase the body's efficiency and capacity. The magnitude of these changes depends largely on the intensity and duration of the training sessions, the force or load used in training, and the body's initial level of fitness. They further stated the body's physiological responses to episodes of aerobic and intermittent exercise occur in the musculoskeletal, cardiovascular, respiratory, endocrine and immune system (Wilmore & Costill 1994).

The body's physiological responses to episodes of training occur in the musculoskeletal, cardiovascular, respiratory, endocrine, and immune systems. These responses have been studied in controlled laboratory settings, where exercise stress can be precisely regulated and physiological responses carefully observed. (Jones & Carter 2000).

Jones & Carter (2000) further reported that HIIT causes adaptations in the pulmonary, cardiovascular and neuromuscular systems that improve the delivery of oxygen from the atmospheric air to the mitochondria and enhance the control of metabolism within muscle cells.

The primary functions of the cardiovascular and respiratory systems are to provide the body with oxygen and nutrients, to rid the body of carbon dioxide and metabolic waste products, to maintain body temperature and acid-base balance and to transport hormones from the endocrine glands to their target organs (Wilmore & Costill, 1994). Wilmore & Costill (1994) found that to be effective and efficient, the cardiovascular system should be able to respond to increased skeletal muscle activity. Low rates of work, such as walking at four kilometres per hour place relatively small demands on the cardiovascular and respiratory systems. However, as the rate of muscular work increases, these two systems will eventually reach their maximum capacities and will no longer be able to meet the body's demands.

Cardiovascular system, composed of the heart, blood vessels, and blood, responds predictably to the increased demands of exercise. With few exceptions, the cardiovascular response to exercise is directly proportional to the skeletal muscle oxygen demands for any given rate of work and oxygen uptake increases linearly with increasing rates of work. The functions of cardiovascular system during exercise are to deliver oxygen to working muscles, to oxygenate blood by returning it to the lungs, to transport heat from the core to the skin, to deliver nutrients and fuel to active tissues and to transport hormones. (Gledhill, Cox & Jamnix, 1994).

Shahana et al. (2010) reported that aerobic exercise stimulates heart, lungs and all working group of muscles and produces valuable changes in body and mind. Many physiological changes are determined by aerobic exercises. Wilmore & Costill (2005) reported that exercise places an increased demand on the cardiovascular system. Oxygen demand by the muscles increases sharply. Metabolic processes speed up and more waste is created. More nutrients are used and body temperature rises. To perform as efficiently as possible the cardiovascular system must regulate these changes and meet the increasing demands of the body.

The cardiovascular system and its components go through various adaptations due to training. The hearts mass and volume increase. Cardiac muscle hypertrophies. It is the left ventricle that adapts in a process known as hypertrophy. The chamber size increases as a result of endurance training, more recent studies show that the myocardial wall thickness also increases (Fagard 1996).

Resting heart rate decreases significantly following training. During a 10-week HIIT programme, an individual with an initial resting heart rate of 80 beats per minute can reasonably expect to see a reduction of about 10 beats per minute in their resting heart rate. During sub-maximal exercise, heart rate is lower at any given intensity compared to pre-training. This difference is more marked at higher relative exercise intensities. For example, at low work rates there may only be a marginal difference in heart rate pre and post training. As intensity reaches maximal levels, the difference can be as much as 30 beats per minute following training (Fagard 1996).

Maximum heart rate tends to remain unchanged by training and seems to be genetically limited. However, there are some reports that maximum heart rate is reduced in elite athletes compared to untrained individuals of the same age. Following an exercise bout, heart rate remains elevated before slowly recovering to a resting level. After a period of training, the time it takes for heart rate to recover to its resting value is shortened. This can be a useful tool for tracking the effects of a training programme. However, it is not so useful to compare to other people as various individual factors other than cardio-respiratory fitness play a role in how quickly heart rate returns to a resting level (Wilmore & Costill, 2005). According to McArdle, Katch & Katch (2000) stroke volume increases at rest, during sub-maximal exercise and maximal exercise following training. Stroke volume at rest averages 50-70 ml/beat in untrained individuals, 70-90ml/beat in trained individuals and 90-110ml/beat in world-class endurance athletes.

This all round increase in stroke volume is attributable to greater end-diastolic filling. This greater filling of the left ventricle is due to an increase in blood plasma and blood volume and reduced heart rate which increases the diastolic filling time. It was further found that according to the Frank-Starling mechanism, this increased filling on the left ventricle increases its elastic recoil thus producing a more forceful contraction. So not only is the heart filled with more blood to eject, it expels a greater percentage of the end-diastolic volume compared to before training (Wilmore & Costill 2005).

Studies by Gledhill, Cox & Jamnix, (1994); Scruggs et al. (1991) showed that cardiac output plays an important role in meeting the oxygen demands for work. As the rate of work increases, the cardiac output increases in a nearly linear manner to meet the increasing oxygen demand, but only up to the point where it reaches its maximal capacity. They further stated that stroke volume in highly trained persons can continue to increase up to near maximal rates of work.

Rowell (1993) reported that the pattern of blood flow changes dramatically from rest to training. At rest, the skin and skeletal muscles receive about 20 percent of the cardiac output. During training, more blood is sent to the active skeletal muscles, and as body temperature increases, more blood is sent to the skin. This process is accomplished both by the increase in cardiac output and by the redistribution of blood flow away from areas of low demand, such as the splanchinic organs. This process allows about 80 percent of the cardiac output to go to active skeletal muscles and skin at maximal rates of work. Training of longer duration, particularly in a hot and humid environment, progressively more of the cardiac output will be redistributed to the skin to counter the increasing body temperature, thus limiting both the amount going to going to skeletal muscle and the exercise endurance.

The mean arterial blood pressure increases in response to HIIT largely owing to an increase in systolic blood pressure, because diastolic blood pressure remains at near-resting levels. Systolic blood pressure increases linearly with increasing rates of work. As the mean arterial pressure is equal to cardiac output times total peripheral resistance, the observed increase in mean arterial pressure results from an increase in cardiac output that outweighs a concomitant decrease in total peripheral resistance. This increase in mean arterial pressure is a normal and desirable response (Rowell, 1993).

The heart rate decreases at rest and during sub-maximal exercise. Stroke volume increases. Cardiac output remains relatively unchanged or decreases only slightly following endurance training. During maximal exercise on the other hand, cardiac output increases significantly. This is a result of an increase in maximal stroke volume as maximal heart rate remains unchanged with training. In untrained individuals, maximal cardiac output may be 14-20L/min compared to 25-35L/min in trained subjects. In large, elite athletes, maximal cardiac output can be as high as 40L.min. Skeletal muscle receives a greater blood supply following HIIT. This is due to increased number of capillaries, greater opening of existing capillaries, more effective blood redistribution and increased blood volume (Wilmore & Costill, 2005).

The diastolic and systolic pressure can decrease at rest and during sub-maximal exercise. However, at a maximal exercise intensity systolic blood pressure is decreased compared to pre-training. Fagard & Tipton (1994). It is interesting to note that although resistance exercises can raise systolic and diastolic blood pressure significantly during the activity, it can also lead to a long-term reduction in blood pressure.

Investigations by Isea et al. (1994) indicated the arterial mixed venous oxygen difference increases with increasing rates of work and results from increased oxygen extraction from arterial blood as it passes through exercising muscle. At rest, the arterial mixed venous oxygen difference is approximately four to five ml of oxygen for every 100 ml of blood. As the rate of work approaches maximal levels, the arterial mixed venous oxygen difference reaches 15 to 16 ml /100 ml of blood.

Marcus (1998) found that the capillary density of the ventricular myocardium can be increased by HIIT. The three major determinants of myocardial oxygen consumption are heart rate, myocardial contractility and wall stress He further reported that a very high correlation exists between both myocardial oxygen consumption and coronary blood flow and the product of heart rate and systolic blood pressure. During HIIT, all three major determinants of myocardial oxygen requirements increase above their resting levels. During prolonged exercise or at higher rates of work, increases in carbon dioxide production, hydrogen ions and body and blood temperatures stimulate further increases in pulmonary ventilation. At higher intensities, the respiratory rate also increases. In highly trained athletes, pulmonary ventilation rates at rest rise to more than 100 litres per minute at maximal rates of work. It was further indicated that HIIT increases blood volume. While plasma volume accounts for the majority of the increase, a greater production of red blood cells can also be a contributory factor. Hematocrit is the concentration of haemoglobin per unit of blood. An increase in red blood cells does not increase hematocrit. This is because blood plasma increases to a greater extent than red blood cells. Hematocrit is actually reduced following training (Coyle, 1991).

HIIT induces both central (cardiovascular) and peripheral (skeletal muscle) adaptations that improve muscular function and improve the body's ability to take in and use oxygen. Such benefits enable individuals to participate in physical activities with less fatigue (Myers, 2012).

The heart beat should drop to 120 beats per minute before the commencement of the next work bout. This type of training can be adapted according to the primary purpose of the activity. There are five variables that can be modified, namely rate and distance of the work interval, number of repetitions and sets during a session, duration of the rest interval type of activity during the rest interval and finally frequency of training per week. HIIT has been shown to be more effective in the principles of overload and progression as any of the five variables can be adjusted (Powers & Hawley, 2004).

Evidence supports HIIT as a potent and time-efficient training method for inducing improved outcomes including improvements in cardiovascular fitness, increased capacity for fat utilisation and improved cardiovascular function Gibala et al. (2008). In many cases, the increase in cardiovascular fitness after HIIT was superior to after continuous moderate-intensity training (Gibala, 2009).

Studies showed that HIIT programmes improve cardiovascular fitness by increasing cardiac output in about three weeks and arterial-venous oxygen difference in about four to six weeks, resulting in a greater maximal endurance capacity. The physiological adaptations associated with HIIT showed enhanced aerobic performance within a period of two to fifteen weeks (Gibala et al., 2008).

HIIT enhances cardiovascular function by increasing cardiac output in four to ten weeks and the arterial-venous difference in two weeks, thus improving maximal VO_{2max} Astorino et al. (2012); Bailey et al. (2009); Talanian et al. (2007); Trilk et al. (2011). Additionally, HIIT has the additional advantage of simultaneously enhancing anaerobic performance by increasing muscle buffering capacity, glycolytic enzymes and ionic regulation (Burgomaster et al., 2005, 2006, 2007; Harmer et al., 2000; Hazell et al., 2012; Stathis et al., 1994).

Several studies have been done on team sport athletes, with most focusing on football Driller et al. (2009); Iaia et al. (2009). The studies used HIIT training with work and rest intervals ranging from fifteen seconds to four minutes at 90 to 100% VO_{2max}, with heart rate values >90% of maximal heart rate and work to rest ratios of 1:1 - 4:1. It was shown in these studies that HIIT elicited increases in cardiovascular parameters

such as heart size, blood flow capacity and arterial distensibility Laughlin et al. (2008); Rakobowchuk et al. (2008, 2009). These changes improved the capacity of the cardiovascular system to transport oxygen, resulting in faster muscle and pulmonary VO_2 kinetics and higher VO_{2max} . This enabled a greater amount of energy to be supplied aerobically, allowing a player to sustain intense exercise for longer durations, as well as recovering more rapidly between high intensity phases of the game (Iaia et al., 2009).

Chittibabu (2013) reported sprint for fast breaks and quick counter attacks require great aerobic capacity. Players with greater aerobic capacity tend to show lower fatigue index. The result of his study showed that HIIT for eight weeks is more effective in increasing aerobic capacity of men handball players. The training load adopted in repeated sprint training with game specific resulted in 11.79% of changes in aerobic capacity. The energy required for handball players during handball match derives energy from both aerobic and anaerobic processes. In this study, anaerobic capacity of the HIIT group showed significant increases of 28.58% (p<0.05), respectively and fatigue index decreased by 38.74% (p<0.05)

Wesserman et al. (1994) indicated that the respiratory system is the integrated system of organs involved in the intake and exchange of oxygen and carbon dioxide between an organism and the environment. In addition to functioning in gas exchange, the respiratory system also participates in regulating blood pH, contains receptors for the sense of smell, filters inspired air, produces sounds and rids the body of some water and heat in exhaled air. Functionally, the respiratory system also consists of the conducting zone which consists of a series of interconnecting cavities and tubes both outside and within the lungs to filter, warm, moisten air and conduct it into the lungs. The respiratory zone consists of tissues within the lungs where gas exchange occurs (Wesserman et al., 1994).

HIIT has a special effect on respiratory system. Oxygen is needed at rest and during exercise and energy supply to the active muscles increases demand of oxygen. Another important function of respiration is to eliminate carbon dioxide from the body. During exercise cellular oxidation and carbon dioxide production increase. The respiratory system maintains an efficient balance between the oxygen and carbon dioxide in the blood at rest and during exercise. There are some immediate changes that occur during HIIT programme. The magnitude of change depends on intensity and duration of exercise. The immediate change that occurs during HIIT is the tidal volume increases to about 2500 mililitres. Non- athletes would not be able to increase up to this level because their capacity is less. (Wesserman et al., 1994)

Gallo et al. (1995) indicated that besides an increase in tidal volume, the respiratory rate increases from 16 to 40 per minute. The pulmonary ventilation of a trained athlete may increase to around 100 litres per minute. This is because their tidal volume and respiratory rates increase. The oxygen uptake of trained athlete increases to approximately 5 litres per minute. The pulmonary ventilation of a trained athlete may increase to around 100 litres per minute of a trained athlete may increase to around 100 litres per minute. This is because their tidal volume and respiratory rates per minute. The pulmonary ventilation of a trained athlete may increase to around 100 litres per minute. This is because their tidal volume and respiratory rates increase during exercise.

The lung diffusion capacity increases with HIIT. Trained athletes may increase their diffusion capacity 30% more than that of an untrained person because trained athletes lung surface area and red blood cell count is higher than that of the non-athletes. The athletes who are under training for a long period may increase vital capacity to around six litres. An athlete's total efficiency of the lung remains at higher level than the non-athletes. This efficiency is the key factor for higher rate of oxygen uptake than non-athletes (Gallo et al.,1995).

There are some relatively permanent changes following long-term HIIT, the magnitude of changes being dependent on type, intensity and duration of exercise. Increased vital capacity, minute ventilation, strength of respiratory muscles and oxygen diffusion are the responses of the respiratory system due to HIIT. Vital capacity is the maximum amount of air that can be released from the body once you have inhaled. The lungs increase in size and results in increases in the vital capacity. An increased vital capacity is beneficial for an athlete as more nutrients and oxygen can be supplied to the muscles. The athlete will able to work without fatigue for a longer period because of the increase in fuel source. Minute ventilation is the amount of oxygen inspired by the body in a minute. During exercise more oxygen is inspired in a minute. More oxygen is supplied to the working muscles. As tidal volume and breathing rate increases, the minute ventilation also increases to meet the demands for oxygen. Increased minute ventilation is beneficial for an athlete because the more oxygen and nutrients that can be inspired in a minute, the better the athlete will be able to work aerobically (Gordon et al., 1995).

Gordon et al. (1995) further reported respiratory muscles include diaphragm and the inter-coastal muscles. These muscles increase in strength which results in greater expansion of the chest cavity. Therefore, more air can move over a longer period of time without fatigue. This is a result of HIIT and increased usage of the respiratory muscles. As the chest cavity expands more efficient inhalation and expiration occur. It indicates that more oxygen can be brought in and more carbon dioxide can be expelled from the body. This increased strength of respiratory muscles can be beneficial to an athlete because when doing aerobic activities the individual will be able to bring in more oxygen to provide the working muscles with energy. Large amount of carbon dioxide is expelled from the body.

Oxygen diffusion rate increases after long term exercise and as a result the oxygen and carbon dioxide will start to diffuse much quickly. When exercise is performed for a long period of time the capillaries increases in size and numbers. This has an impact on the movement of oxygen and carbon dioxide because the wider the capillaries, more oxygen is diffused from the capillaries to the tissues and more carbon dioxide is diffused from the cells to the blood. In a trained athlete transportation of oxygen and carbon dioxide is maximal. When the supply of oxygen increases the athlete would be able to work at better intensity. With better the transportation of carbon dioxide, the athlete will be less prone to fatigue (Gordon et al., 1995).

2.5 HIIT and physiological adaptations in the muscular and metabolic system

The primary purpose of the musculoskeletal system is to define and move the body. To provide efficient and effective force, muscle adapts to demands. In response to demand, it changes its ability to extract oxygen, choose energy sources and rid itself of waste products.

Adaptations to HIIT in the muscles can occur at two levels. Firstly muscle adaptations can occur at a structural level where there is a modification of actin and myosin (Birch et al., 2005). Secondly adaptations to training can occur at a functional level whereby there is an increase in the maximal activities of cytoplasmic enzymes, as well as an increase in mitochondrial density, either an increase in the number of mitochondria or mitochondria size, or both. The increase in mitochondrial density triggers an increase in the aerobic enzymes Kraemer et al. (2012). For instance, Hawley & Stepto (2001) reported a 95% increase in succinate dehydrogenase, an enzyme involved in the Krebs cycle in endurance trained cyclists.

There is a direct relationship between predominant fibre type and performance in certain sports. For example, in most marathon runners, slow-twitch fibres account for up to or more than 90 percent of the total fibres in the leg muscles. On the other hand, the leg muscles in sprinters are often more than 80 percent composed of fast-twitch fibres. Although the issue is not totally resolved, muscle fibre type appears to be genetically determined. HIIT do not significantly alter the percentage of the two major types of fibres (Terjung, 1995). Medbo & Burges (1990) found that the increase in power after HIIT programme could be partly related to the increases in muscular performance or muscle-fibre size for muscle force production have been associated with increases in muscle fibre size. Developing muscle performance with a training programme might also be partly related to increase motor unit function or neuromuscular adaptation. Their study indicated that neuromuscular adaptations such as increased inhibition of antagonist muscles and contraction of synergistic muscles might account for improvements in power output.

Terjung (1995) indicated HIIT also increases the number of capillaries in trained skeletal muscle, thereby allowing a greater capacity for blood flow in the active muscle. Resistance-trained skeletal muscle exerts considerably more force because of both increased muscle size (hypertrophy) and increased muscle fibre recruitment. Kannus et al (1992) discovered that fibre hypertrophy is the result of increases in both the size and number of myofibrils in both fast-twitch and slow-twitch muscle fibres.

Daussin et al. (2008) an increase in capillary density has been reported as part of the adaptations invoked by HIIT. This is an important adaptation as capillary density determines the delivery of oxygen, blood glucose and triglycerides to working muscles, as well as the rate of removal of carbon dioxide, lactate and other metabolic byproducts. The increase in capillary density was observed in three ways, which included an increase in capillary number, an increase in the number of capillaries per muscle fibre and increase in the number of capillaries per square millimetre. The increase in the number of capillaries surrounding each muscle fibre is important in that it helps maintain conditions which are conducive for aerobic metabolism by increasing the efficiency of the muscles oxidative capacity. Further, they compared the effect of eight weeks of endurance training and HIIT on muscle capillary density in sedentary women and men. They reported an increase of 3% and 2% for the endurance training and HIIT, respectively. This showed that HIIT caused similar changes in capillary density to endurance training.

Hyperplasia or increased fibre number has been reported in animal studies Sjöström et al. (1991) where the number of individual muscle fibres can be counted and has been indirectly demonstrated during autopsies on humans by using direct fibre counts to compare dominant and non-dominant paired muscles. They further reported active muscles can undergo changes that lead to muscle soreness. Some soreness is felt immediately after exercise, and some can even occur during exercise.

Individuals who are sedentary generally have less bone mass than those who exercise. The increases in bone mineral and mass that result from HIIT are relatively small. HIIT little demonstrated positive effect on bone mineral and mass (Chesnut, 1993).

Several studies indicate that ligaments and tendons become stronger with HIIT This effect is the result of an increase in the strength of insertion sites between ligaments, tendons, and bones, as well as an increase in the cross-sectional areas of ligaments and tendons. These structures also become weaker and smaller with several weeks of immobilization which can have important implications for musculoskeletal performance and risk of injury (Tipton & Vailas, 1990).

Significant metabolic adaptations occur in skeletal muscle in response to HIIT (Kiens et al. 1993). Both the size and number of mitochondria increase substantially, as does the activity of oxidative enzymes. They further confirmed that myoglobin content in the muscle can also be augmented, increasing the amount of oxygen stored in

individual muscle fibres. Such adaptations, combined with the increase in capillaries and muscle blood flow in the trained muscles greatly enhance the oxidative capacity of the endurance-trained muscle. Endurance training also increases the capacity of skeletal muscle to store glycogen. The ability of trained muscles to use fat as an energy source is also improved.

The skeletal muscular adaptive response to HIIT is highly dependent on the frequency, intensity and volume of work performed (Ross & Leveritt, 2001). In terms of muscle fibre composition, several studies have reported shifts of Type I and Type IIx fibres to Type IIa fibres, similar to the general trend observed after both endurance training and HIIT (Kubukeli et al., 2002; Ross & Leveritt, 2001).

HIIT does not have a major effect on muscle size, especially compared to heavy resistance training, although there may be a modest but significant hypertrophy of both Type I and Type II fibres after many months of HIIT (Ross & Leveritt, 2001). It has long been recognized that HIIT also has the potential to increase muscle oxidative capacity and exercise performance during tasks that mainly rely on aerobic energy metabolism.

According to Gibala et al. (2006), a few studies have directly compared changes in muscle oxidative capacity after HIITl versus continuous training in humans with equivocal results. Moreover, every study that examined muscle oxidative capacity after HIITl versus continuous exercise training had used a matched-work design in which total work was similar between groups. Gibala et al. (2008) reported that during training, the muscles use inspired oxygen to burn the fuel in mitochondria, which are the microscopic power stations of cells. Due to the high intensity nature of HIIT, there is a high muscle fibre recruitment and stress on fast twitch muscle fibres. This stress causes an increase in mitochondrial content in the muscle, which therefore increases the capacity to utilise oxygen thus improving fitness and increasing fat burning capacity.

Burgomaster et al. (2006; 2007) found that in addition to an increased skeletal muscle oxidative capacity after two weeks of HIIT, changes in carbohydrate metabolism including an increased resting glycogen content and reduced rate of glycogen utilization during matched-work exercise and increased total glucose transporter type 4 (GLUT- 4) protein content in muscle. But after short-term Wingate-based training intervention they found no changes in selected markers of fatty acid metabolism, including the maximal activity of β-hydroxyacyl-CoA dehydrogenase (HAD) and the muscle contents of fatty acid translocase (FAT/CD36) or (FABPpm), a fatty-acid-binding protein associated with the plasma membranes.

In contrast, Talanian et al. (2007) reported that seven sessions of HIIT over two weeks increased the maximal activity of HAD, the muscle protein content of FABPpm, and whole-body fat oxidation during 60 min of cycling at 65% pre-training VO_2 max.

Baar (2006) indicated that the potency of HIIT to elicit rapid changes in skeletal muscle was related to its high level of muscle fibre recruitment and potential to stress type-II fibres in particular but the underlying mechanisms were not clear. When trying to determine what molecular signals was developed that led to adaptations in muscle, exercise was typically classified as either strength or endurance with short duration, high intensity work usually associated with increased skeletal muscle mass and prolonged, low-to-moderate-intensity work associated with increased mitochondrial mass and oxidative enzyme activity.

Wilmore & Costill (1994) found aerobic metabolism recruits primarily type one muscle fibres which have a high oxidative capacity as they have more mitochondria, high capillary density and a higher resistance to fatigue. Dawson et al. (1998) reported a decrease in the proportion of type II fibres in fit males who trained for six weeks using six 40 minute sprints interspersed by 24 seconds of recovery. These results showed that HIIT has the potential to alter muscle fibres composition towards greater endurance capacity. Endurance training also increases cardio-respiratory fitness

The rate at which the body uses energy is known as the metabolic rate. Metabolic processes are responsible for generating ATP, the body's energy source for all muscle action. ATP is generated by three basic energy systems: the ATP PC, the glycolytic and the oxidative system. Each system contributes to energy production in nearly every type of exercise. The relative contribution of each will depend on factors such as the intensity of work rate at the onset of exercise and the availability of oxygen in the muscle. Typically, carbohydrate and fat provide most of the ATP; under most conditions, protein contributes only 5 to 10 percent at rest and during exercise. To quantify the rate of energy expenditure during exercise, the metabolic rate at rest is defined as one metabolic equivalent (MET); a four MET activity thus represents an activity that requires four times the resting metabolic rate. The use of METs to quantify physical activity intensity is the basis of the absolute intensity scale (Turley, McBride & Wilmore, 1993).

Oxygen uptake during exercise (VO₂) increases in direct proportion to the rate of work. The point at which VO₂ is no longer able to increase is defined as the maximal oxygen uptake (VO_{2 max}). 'VO_{2max} is in part genetically determined; it can be increased through training until the point that the genetically possible maximum is reached. VO_{2max} is considered the best estimate of a person's cardio-respiratory fitness or aerobic power (Neiman, 1994).

Lactate is the primary by-product of the anaerobic glycolytic energy system. At lower exercise intensities, when the cardio-respiratory system can meet the oxygen demands of active muscles, blood lactate levels remain close to those observed at rest, because some lactate is used aerobically by muscle and is removed as fast as it enters the blood from the muscle. As the intensity of exercise is increased, however, the rate of lactate entry into the blood from muscle eventually exceeds its rate of removal from the blood, and blood lactate concentrations increase above resting levels. From this point on, lactate levels continue to increase as the rate of work increases, until the point of exhaustion (Neiman, 1994).

Reichlin (1992) stated that the point at which the concentration of lactate in the blood begins to increase above resting levels is referred to as the lactate threshold. Lactate threshold is an important marker for endurance performance, because distance runners set their race pace at or slightly above the lactate threshold. Further, the lactate thresholds of highly trained endurance athletes occur at a much higher percentage of their VO_{2max} , and thus at higher relative workloads, than do the thresholds of untrained persons. This key difference is what allows endurance athletes to perform at a faster pace.

The endocrine system, like the nervous system, integrates physiologic responses and plays an important role in maintaining homeostatic conditions at rest and during exercise. This system controls the release of hormones from specialized glands throughout the body, and these hormones exert their actions on targeted organs and cells. In response to an episode of exercise, many hormones are secreted at an increased rate (Reichlin, 1992).

The studies by Parolin et al. (1999) reported that during a single 30 second all out burst of maximal cycling, approximately 20% of total energy provision is derived from oxidative metabolism. However, if the exercise bout is repeated three times with four minute of recovery between bouts, ATP provision during the third bout is derived primarily from oxidative metabolism. The increased contribution from oxidative metabolism during repeated high-intensity efforts is attributable to both an increased rate of oxygen transport and utilization and a decreased ability to stimulate ATP production through the breakdown of phosphocreatine and glycogen.

HIIT is therefore unique because cellular energy during an acute bout or a given training session can be derived primarily from non-oxidative or oxidative metabolism. Kubekeli et.al. (2002). Consequently, it can elicit a broad range of physiological adaptations. Improved performance of sprints or high-intensity exercise after HIIT is related in part to increases in the maximal activities enzymes that regulate non-oxidative energy provision (Juel et al., 2006; Kubukeli et al., 2002; Ross & Leveritt, 2001).

MacDougall et al. (1998) reported an increased VO_{2max} and increased maximal activities of several mitochondrial enzymes after a Wingate based HIIT protocol in which subjects performed 4-10 intervals per day, three times per week for seven weeks.

However, until recently little was known regarding the early time course and minimum volume of training necessary to elicit these adaptations or the effect of HIIT on metabolic control during aerobic based training.

Improvement in fitness depends on the frequency, intensity, duration of exercise programme, the mode of exercise, the regularity of exercise and age. HIIT training leads to rapid improvement in $VO_{2 max}$ and endurance performance (Hawley et al., 1997). In addition to its effect on VO_{2max} , HIIT can improve athletic performance. Lindsay et al. (1996) reported that four weeks of interval training can improve 40 kilometre time trial performance of competitive cyclists.

Researchers from Canada's McMaster University investigated the effects of interval exercise on VO_{2max} . VO_{2max} increased by 9%, demonstrating that significant gains in VO_{2max} could be achieved from exercise of a relatively short duration. This group cycled for a total of only 20 min per week, yet their VO_{2max} improved by 15% (MacDougall et al., 1998).

Rodas et al. (2000), reported HIIT programme increases oxidative enzyme activity in muscle. A study on aerobic and anaerobic metabolism was observed. Subjects performed two weeks of daily HIIT consisting of two 15 second all-out bouts separated by 45 seconds of rest, followed by two bouts of 30 second all-out sprints separated by 12 minutes of rest. Every two training sessions, an extra work bout was added. The last three sessions consisted of seven bouts of 15 seconds and seven bouts of 30 seconds. VO_{2max} increased and there were substantial increases in activity of citrate synthase and 3-hydroxyacyl-CoA dehydrogenase These changes in oxidative enzyme activity increased the rate of fat oxidation and reduce carbohydrate oxidation.

It was interesting to note that an increase in training intensity can improve endurance performance without a change in VO_{2max}. Hawley et al. (1997) tracked a group of trained male distance runners who increased their training intensity to 90-95% maximum heart rate for eight weeks. There was an average 63 second reduction in 10kilometre race time and a significant decrease in plasma lactate at 85 and 90% of VO_{2max}, but no substantial change in VO_{2max} (65.3 \pm 2.3 versus 65.8 \pm 2.4 ml.kg⁻¹.min⁻¹).

Laboratory studies have demonstrated that the increase in oxidative capacity after HIIT training is a result of an increase in the mitochondrial enzymes. First there is an increase in the maximal activity of the enzyme citrate synthase which has been observed ranging from 5 to 35% in healthy subjects after HIIT (Burgomaster et al., 2006; Little et al., 2010; Perry et al., 2008; Talanian et al., 2007).

Burgomaster et al. (2006) reported an 11% up regulation of the maximal activities of citrate synthase in recreationally active men after two weeks of Wingate sessions. Talanian et al. (2007) in their study involving recreationally active women reported a 20% increase in citrate synthase following seven HIIT sessions over a two week period. Perry et al. (2008) also reported an increase in the activity of citrate synthase enzyme of 26% following six weeks of HIIT. Little et al. (2010) reported a 16% and 20% increase in the maximal activities and protein content of citrate cynthase in their modified HIIT protocol in young healthy men. The improvement in the muscle's oxidative capacity enhances the oxidation of fat thus reducing the risks of metabolic disorders such as insulin resistance (Gibala, 2009).

Another enzyme that has been shown to increase its activity after HIIT training is Cytochrome oxidase subunit 4 (COX4) and this was also within as short a period as two weeks. This is especially interesting because these findings are similar to those shown after endurance training with a vast difference in total exercise times. Burgomaster et al. (2007) reported a 35% increase in COX 4 in healthy active men after only one week of HIIT, using the Wingate protocol. Subsequently Perry et al. (2008) reported an 18% increase in COX4 following seven weeks of HIIT in physically active men.

Increases in the maximal activities of malate aspartate and pyruvate dehydrogenase have also been reported following HIIT. A 26% increase in the maximal activities of malate aspartate (enables the oxidation of NADH) and 21% increase in pyruvate dehydrogenase have been observed, resulting in an increase in carbohydrate and fat oxidation capacities (Perry et al., 2008). Another enzyme, succinate dehydrogenase, which is a key enzyme in the Krebs cycle, has also been reported to increase after HIIT. MacDougall et al. (1998) reported a 65% increase in succinate dehydrogenase following seven weeks of HIIT in physically active men.

HIIT has also been shown to increase anaerobic capacity, as demonstrated by an up regulation of glycolytic enzymes. This was demonstrated by MacDougall et al., (1998) when they reported increases in the maximal activities of hexokinase (56%) and phosphorfructokinase (49%) following HIIT. Daussin et al. (2008) to conclude, the increases in the muscle's oxidative capacity observed after HIIT is related to the fluctuations in workloads, rather than exercise duration and net total energy expenditure.

Training at higher intensities subsequently decreases the ATP-ADP ratio, signalling an increase in the muscle's reliance on carbohydrate oxidation, resulting in greater production of ATP per molecule of glucose (ATP : O2 = 3) than fat (ATP: O2 = 2.8) (Atwood & Bowen, 2007; Noakes, 2001).

HIIT improves the body to sustain strenuous activities for long periods and improves aerobic metabolism Gibala & McGee, (2008). Research evidence indicated improvements in mean peak power output and time trial performances. Burgomaster et al. (2006) reported an improvement of 9.6% (p = 0.04) in the time taken to complete a 250 kJ cycle trial (equal to 10km) after two weeks of Wingate sessions, while mean power output increased by 5.4% (p = 0.04). Perry et al. (2008) also reported a 21% (p < 0.05) increase in peak power output in healthy, physically active men and women after six weeks of HIIT. Improvements were also demonstrated by Hazell et al. (2010) who used physically active men and women in their two week HIIT protocols reported an increase in time trial performance of 5.2%, 3.5% and 3.0% in the different groups.

Similarly Little et al. (2010) reported an improvement in time trial performance of 11% (p = 0.04) and 9% (p = 0.05) in the 50kJ and 750kJ respectively. This was after a two week HIIT intervention programme in recreationally active men (Little et al., 2010). Astorino et al. (2011) also reported an increase in mean power output of 10.4% in men and 10.9% in women during cycle time trials. These studies collectively show that even very short HIIT interventions can significantly improve performance.

Wilmore & Costill (1994) found aerobic metabolism recruits primarily type one muscle fibres which have a high oxidative capacity as they have more mitochondria, high capillary density and a higher resistance to fatigue. Dawson et al. (1998) reported a decrease in the proportion of type II fibres in fit males who trained for six weeks using six 40 minute sprints interspersed by 24 seconds of recovery. These results showed that HIIT has the potential to alter muscle fibres composition towards greater endurance capacity. Endurance training also increases cardio-respiratory fitness.

Manna, Khanna & Dhara (2009) provided evidence that anaerobic performance can be enhanced by HIIT programme. It was further reported that maximal-intensity intermittent training has different training effects on anaerobic performance. Tabata et al. (1996) reported HIIT was developed after researchers observed that higher intensity intervals resulted in greater improvement in anaerobic capacity and aerobic power.

HIIT for eight weeks enhanced muscle enzyme activities (Parra et al., 2000). Another mechanism affecting improvement of anaerobic performance is cellular regulations providing the continuity of energy production. Maximal intensity training is suggested to increase anaerobic performance due to the improvement of cellular regulations. According to Edge, Bishop & Goodman, (2006); Silva et al. (2007) these regulations in the cellular mechanism buffer metabolic acidosis, which increases during exercise, causing fatigue; thus fatigue may be delayed or the resistance to fatigue may increase. Therefore, it was assumed that the anaerobic performance of male handball players might be improved by increasing both muscle buffering capacity and enzyme activities which are both affected by training stimulus. HIIT after 10 weeks stimulates metabolic adaptations in skeletal muscle and improves aerobic capacity (Babraj et al., 2009; Burgomaster et al., 2005, 2006, 2007, 2008; Gibala et al., 2006a, 2012; Gibala & McGee, 2008 & Parra et al., 2000). HIIT has also been shown to increase anaerobic capacity, as demonstrated by an up regulation of glycolytic enzymes. This was demonstrated by MacDougall et al. (1998) when they reported increases in the maximal activities of hexokinase (56%) and phosphorfructokinase (49%) following HIIT. Daussin et al.(2008) to conclude, the increases in the muscle's oxidative capacity observed after HIIT is related to the fluctuations in workloads, rather than exercise duration and net total energy expenditure).

However, intense anaerobic exercise requires considerable participant motivation, which likely impacts its general prescription. Recently, more practical HIIT models have been introduced, involving bouts of extended duration at a lower intensity interspersed with appropriate recovery periods (Little et al., 2011).

Edge et al. (2006) reported HIIT causes a substantial increase in the local production of lactic acid and hydrogen ions (H+) which will lead to an increase in the acidity of the blood. Birch et al. (2005) & Kreamer et al. (2012) discovered an increase in acidity is detrimental to performance because it inhibits the optimal activities of enzymes involved in energy metabolism, such as phosphofructokinase (PFK), ATPases and glycogen phosphorylase. Kraemer et al. (2012) stated that lowering of pH affects the release of calcium from the sarcoplasmic reticulum and impairs the binding of calcium to troponin-C in the cross bridges. Juel (1999) reported lactate can be removed from muscle through the sarcolemmal transporters, monocarboxylate transporter 1 (MCT1) and monocarboxylate transporter 4 (MCT4). These transporters are stereo selective for lactate and depend on the pH gradient for transportation.

It has been suggested that HIIT increases the muscle's buffering capacity (Edge et al., 2006; Hashimoto et al., 2007). Edge et al. (2006) compared the effects of HIIT and continuous training on muscle buffering capacity in young recreationally active women in a five week cycling study. The HIIT and continuous protocols were matched for total work done. They reported a significant increase in muscle buffer capacity (25%, p < 0.05) compared to the continuous training group (2%; p > 0.05). Thus it was suggested that the higher intensity of training might be a more potent stimulus to induce improvements in muscle buffer capacity compared to continuous training group.

Edge et al. (2006) suggested that the duration of the work bouts and the rest periods largely influences the muscle pH regulating systems. It seems that short intervals of one minute exercise and recovery each lead to a decrease in intracellular buffer capacity, while three minute rest periods between the one minute bouts resulted in an increase in intracellular buffering capacity.

This suggestion was supported by Bishop et al. (2008), namely that short recovery periods between work bouts facilitate a decrease in the muscle's buffering capacity and no absolute change in the expression of MCT1. Mannion et al. (1993) this could be attributed to the reduction of the intracellular buffers (phosphate) after training because of the great acidic load placed on the body during HIIT. Bishop et al. (2008) & Krustrup et al. (2006) investigated the accumulation of lactate and hydrogen ion (H+) in muscle after training have reported a reduction in lactate and H+ production. Philip et al. (1995) found that this reduction in lactate and H+ was likely due to an increase in lactate removal or a reduction in lactate production.

Burgomaster et al. (2007) showed an increase in the sarcolemmal lactate proton co-transporters after HIIT. An increase in these co-transporters indicates an enhanced rate of lactate removal. Further, it was reported a 50% increase in MCT1 and 44% increase in MCT4 after just a week of HIIT training. Similarly, Perry et al. (2008) reported a 14% and 16% increase in MCT2 and MCT4 protein content thus enhancing lactate removal capacity. In summary, HIIT training has been shown to enhance the rate of lactate removal in the muscles leading to an increase in exercise capacity.

Burgomaster et al. (2008) suggested that a minimum volume of intense interval training is necessary to induce adaptations in lipid metabolism. Gibala (2007) reported HIIT has also been shown to increase the body's utilization of fat and reduce its reliance on glucose and glycogen. Little et al. (2011) found increases in glycogen content as shown by higher resting muscle glycogen levels (17%) following HIIT, whilst reducing the rate of glycogen utilization by the muscle. Perry et al. (2008) reported a 59% increase in glycogen content following six weeks of HIIT. The benefit of an increase in substrate availability is that it enhances one's capacity to sustain exercise for a longer duration.

2.5 Metabolic adaptations to sprint training

Sprint training (ST) is a form of anaerobic training characterised by its short durations of activity lasting less than 30 seconds at maximal exercise intensities (Harmer et al., 2000). ST can vary in form, for instance it can be performed by running or cycling and differ in distance and recovery periods (Gibala & McGee 2008).

ST has been shown to increase anaerobic power due to metabolic adaptations involving enzymes such as myokinase (MK) and creatine phosphokinase (CPK) as well as changes in the breakdown rate of adenosine triphosphate (ATP) and phosphocreatine (PCr) (Ross & Leveritt, 2001; Spencer et al., 2005).

In addition, there are changes in enzymatic activities in anaerobic glycolysis involving lactate dehydrogenase (LDH), glycogen phosphorylase (PHOS) and phosphofructokinase (PFK) and contribution from aerobic pathways as well (Ross & Leveritt, 2001). As many sports require the ability to generate energy rapidly for activities such as cycling, field sports and track and field (Creer et al., 2004; Spencer et al. 2005) it is very important for strength and conditioning coach to understand the metabolic adaptations of ST and its consequence on athletic development and sports selection.

Ross & Leveritt, (2001) the ability of a muscle to produce energy is associated with three different metabolic adaptations. These involve an increase in enzymatic activity or energy stores in the muscles and the muscle's ability to deal with and eliminate waste associated with fatigue from energy production (Burgomaster et al., 2005).

Parra et al. (2000) reported that two weeks of daily ST increased citrate synthase maximal activity but did not change anaerobic work capacity, possibly because of chronic fatigue induced by daily training. It was further reported that the effect of fewer ST sessions on muscle oxidative potential is unknown and aside from changes in $\dot{V}O_2$ max, no study has examined the effect of ST on aerobic exercise capacity.

Performing repeated bouts of ST over several weeks or months induces profound changes in skeletal muscle. A wide range of muscle metabolic and morphological adaptations have been described however, the magnitude and direction of change in many variables depend on the nature of the training protocol, namely the frequency, intensity and duration of sprint efforts as well as the recovery between bouts (Mac Dougall et al., 1998; Ross & Leveritt, 2001).

Given the significant contribution from aerobic energy metabolism during repeated sprinting (Bogdanis et al., 1996; Mc Kenna et al. 1997 & Parolin et al., 1999), it is not surprising that an increase in muscle oxidative potential, as indicated by changes in the maximal activities of marker enzymes such as citrate synthase, has been reported after six to eight weeks of ST.

Two studies reported large increases in citrate synthase maximal activity, as well as $VO_{2 max}$ after only two weeks of daily sprint training (Rodas et al., (2000) & Parra et al. (2000). These data suggest that improvements in aerobic energy metabolism can be rapidly stimulated by brief bouts of very intense exercise. In addition, aside from changes in $\dot{V}O_{2 max}$, no data suggested that ST leads to an increased ability to perform exercise that is primarily aerobic in nature.

Understanding the metabolic adaptations to ST in a specific population is important for the coach when devising a training plan, as it will influence training modality to better suit the athlete's background and sports demand Farpour-Lambert et al. (2000); Lätt et al. (2010).
Adolescence is a very important stage in athletic development that is marked by many physiological and musculoskeletal changes Farpour-Lambert et al. (2000). By the time a male athlete reaches adolescence they are usually starting to compete in their chosen sport (Robertson & Way, 2005).

Manipulation of training methods such as frequency and volume, duration and exercise intensity as well as recovery periods can lead to different metabolic adaptations (Rodas et al., 2000; Parra et al., 2000). Provided the coach understands the metabolic adaptations to certain forms and variations of training, such as of ST, they could potentially enhance the training of athletes, benefiting their long-term performance. As noted before, regulation of energy production is affected by enzyme activity (Ross & Leveritt, 2001).

During sprint activities of less than 10 seconds there is a great demand on PCr breakdown and ATP resynthesis and when exercise duration increases different energy pathways are utilised such as glycolysis and aerobic pathways Spencer et al. (2005). ATP provides muscles with the required immediate source of energy in highly demanding physical activities. ATP is resynthesised from adenosine diphosphate (ADP) by the myokinase enzyme (MK) which has been shown to increase in both short sprints lasting less than 10 seconds and longer sprints of 15 seconds or more (Ross & Leveritt, 2001).

Dawson et al. (1998) investigated the effects of ST lasting less than 10 seconds in nine trained adult male subjects and reported non-significant increases in MK activity after six weeks of training. However, earlier studies found significant increases in MK activity in male athletes post ST of 30 seconds long as well as an increase in ATP and PCr stores. This study was over a longer period lasting eight weeks with more frequent sessions and shorter recovery periods. Despite existing evidence suggesting ST increases MK activity, the connection between enhanced performance and increases in ATP resynthesis remains somewhat unclear in athletes (Ross & Leveritt, 2001).

During sprints of up to 30 seconds, ATP stores usually deplete to half of their resting state or less, with this value being lower the shorter the sprints (Spencer et al., 2005). On the other hand studies have shown significant decreases of PCr stores in the muscle during high intensity exercise with duration not having a major impact as stores deplete rapidly (Spencer et al., 2005).

The breakdown of PCr is catalysed by the enzyme creatine phosphokinase (CPK), which has been shown to increase as a result of ST (Parra et al., 2000), however there is also research that shows increases in PCr breakdown with no changes in CPK in adolescent athletes (Cadefau et al., 1990). This can be because of the different testing methodologies used by researchers or the initially high levels of CPK (Cadefau et al., 1990).

Energy production from ATP resynthesis and PCr breakdown have been shown to contribute to less than 40% of energy production in sprint activities lasting less than 30 seconds (Spencer et al., 2005). It is also now clear that anaerobic glycolysis starts to contribute instantly to metabolic energy from the commencement of physical activity and this contribution increases with the length of the activity overtaking the initial contribution of PCr breakdown (Ross & Leveritt, 2001; Spencer et al., 2005).

In activities lasting 15 to 30 seconds or activities that require short repeated sprints over a longer duration, there is a greater contribution from anaerobic glycolysis Burgomaster et al. (2005). Cadefau et al. (1990) found that ST leads to a significant

increase in muscle glycogen stores in adolescent male athletes. According to Burgomaster et al. (2005), increased glycogen stores as a result of ST can improve endurance capacity by delaying the onset of muscle fatigue. In a study by Rodas et al. (2000) looking at anaerobic metabolism, significant increases were shown in PCr and glycogen post ST involving 15 seconds all out bouts on cycle ergometer followed by 45 seconds rest and also in 30 seconds all out exercise followed by 12 minutes rest. The study shows significant increases in CPK, Phosophofructokinase (PFK) and Lactate dehydrogenase (LDH) but did not find any performance gains post 30 seconds sprint. Interestingly, it did show that using a progressive method improved maximum oxygen consumption.

Increases have been shown in the enzyme LDH that catalyses pyruvate into lactate and the enzyme PHOS that mobilises muscle glycogen in ST and long duration (MacDougall et al., 1998; Linossier et al.1993) suggest that anaerobic glycolysis can be linked to increases in energy production as lactate production was shown to increase post training along with a 20% increase in PFK and LDH. However Cadefau et al. (1990) found no changes in LDH levels only significant increases in PFK post ST and neither enzyme can be directly linked to enhanced sprint performance (Ross & Leveritt, 2001)

During short high intensity activities the aerobic energy pathway also has a contribution to energy metabolism that increases the longer the activity lasts or if rest times are kept short, with citrate synthase (CS) and succinate dehydrogenase (SDH) showing changes in sprints of longer duration Rodas et al. (2000). Dawson et al. (1998) showed significant improvement in VO_{2max} performance as well as an increase in PHOS activity but a decrease in CS activity using ST of less than 10 seconds.

Gibala & McGee (2008) also reported improvements in endurance performance following intermittent ST protocol of 15 minutes of highly demanding exercise over two weeks with increases in VO_{2peak} . Cadefau et al. (1990) found a significant increase in succinate dehydrogenase (SDH) post ST in adolescent athletes after eight months

Although ST has been shown to cause improvements across the different energy pathways including the aerobic system Dawson et al. (1998), the role of CS and SDH are still not clear as research into the effects of ST on endurance performance is still limited (Ross & Leveritt, 2001). Linossier et al. (1993) and Cadefau et al. (1990) both state that ST can lead to major adaptations to the athlete metabolic performance that continue even if training is ceased for a lengthy period of time before they return to baseline data. Ross & Leveritt, (2001); Cadefau et al. (1990) ST training not only has consequences on metabolic adaptations but also leads to morphological adaptations, the knowledge of which is very important in early athletic development

Research by Dawson et al. (1998) using short sprints of less than 10 seconds demonstrated an increase of muscle fibers of type II. It is interesting to note that this study utilised short rest periods of 24 seconds whereas in another study examining muscle fibre composition, Jansson et al. (1990) also found an increase in type IIa muscle fibres using 30 seconds of high intensity sprints on Wingate bicycle followed by 15-20 minutes of rest. This shows that ST induces muscle fibre adaptations possibly caused by increased fibre activation regardless of actual rest times (Jansson et al., 1990). Cadefau et al. (1990) reported a significant increase in type I muscle fibres post ST in adolescent male athletes accompanied by increases in only type IIa fibres. There was also an increase in glycogen muscle stores and hypertrophy was evident in both type I and II fibre In another research examining muscle metabolites Karatzaferi et al. (2001) found that ATP breakdown was greatest in IIa fibres whereas PCr breakdown occurred across all muscle fibre types.

Therefore it can be concluded that ST causes morphological adaptations that lead to further metabolic adaptations via enzymatic activity changes and energy storage, which can be advantageous for many sports. Bangsbo, Mohr, & Krustrup (2006) state that during a football game for example, a player can perform up to 250 bouts of intense movement that creates high demand on the rates of PCr breakdown and utilisation of glycogen via glycolysis. Hence, it is extremely important for the athlete to be able to breakdown energy quickly and recover efficiently.

In another study looking at the effects of ST, Markovic et al. (2007) determined that ST is as or more effective in producing performance gains in muscle function and athletic performance. The researchers found significant improvements across a range of tests and recommend ST as an important tool in developing explosive performance.

In a study by Sharp et al. (2008) looking at muscle buffer capacity, results concluded that ST can also increase muscle buffer capacity due to changes in lactate concentration not seen in endurance training (ET). On the other hand, Fournier et al. (1992) investigated the metabolic and morphological effects of sprint and ET in adolescent boys and found that ET resulted in significant increases in VO_{2max} and slow twitch muscle fibre surface area as well as SDH activity whereas ST only resulted in

increased PFK activity. Measures in both ST and ET returned to baseline data after a period of detraining. It is clear that the different methodologies used by researchers can results in contrasting results however the overall consensus shows ST has many benefits that an athlete can benefit from.

In summary, using ST as tool not only improves anaerobic energy metabolism but can also enhance aerobic fitness. Although more research is required to support this information in adolescent male athletes, improvements in glycogen metabolism are likely to help young athletes train for longer by resisting fatigue. The athlete can also benefit from the morphological adaptations resulting in the development of type II muscle fibre type if required by their sport. A coach can manipulate sprint time, rest duration, frequency and volume to induce different adaptations that can be retained for an expensive period of time after detraining (Ross & Leveritt, 2001).

ST for 10 weeks enhanced muscle enzyme activities (Parra et al., 2000). Another mechanism affecting improvement of anaerobic performance is cellular regulations providing the continuity of energy production. Maximal intensity training is suggested to increase anaerobic performance due to the improvement of cellular regulations. These regulations in the cellular mechanism buffer metabolic acidosis, which increases during exercise, causing fatigue; thus fatigue may be delayed or the resistance to fatigue may increase. Therefore, it was assumed that the anaerobic performance might be improved by increasing both muscle buffering capacity and enzyme activities which are both affected by training stimulus (Edge, Bishop & Goodman, 2006; Silva et al., 2007).

CHAPTER 3: METHODOLOGY

Methodology and research design direct the researcher in planning and implementing the study in a way that is most likely to achieve the intended goal. It is a blueprint for conducting the study (Burns & Grove 1998). They further stated methodology includes the design, setting, sample, methodological limitations and the data-collection and analysis techniques in a study. This chapter describes the research design and methodology, including sampling and data collection and analysis.

The main objective of the study is to assess the effectiveness of a 10 week training programme on physical parameters in Malaysian Football Referees. The physical parameters assessed in the study are repeated short sprints, repeated high intensity intermittent runs and aerobic power.

3.1 The Design of the Study

This study is experimental in nature and used pre-test and post-test to carry out the measurement of repeated short sprints, repeated high intensity intermittent runs and aerobic power using The FIFA Fitness Test.

It will focus upon individual performances in the pre-test. After 10 weeks to determine if referees improved their performance in repeated short sprints, repeated high intensity intermittent runs and aerobic power, baseline testing is repeated.

3.2 Participants

The total population of elite football referees in Malaysia in the year 2012 was 120. Though they were all registered with the Football Association of Malaysia (FAM) which is situated in Selangor, the referees resided and worked far away in various states including Sabah and Sarawak. The distribution of referees in various states is shown in Appendix A. These elite referees gather twice a year in FAM for seminars. For the purpose of this study, purposive sampling technique was used and all the 60 referees from Selangor and Kuala Lumpur (50% of the total population) were chosen to participate. This was because the referees who volunteered for the study had to attend training three days in a week for 10 weeks. The venue for the training to be carried out is in Kuala Lumpur. It is not feasible for referees who stayed hundreds of miles away from Kuala Lumpur to participate in the study. Therefore, FAM decided that only elite referees from Selangor and Kuala Lumpur to participate in the study.

The researcher made contact with the participants through the use of telephone and emails for participation in his study. Letters were sent explaining the objectives of this study and to seek their agreement to voluntarily participate. Contact number and email address of researcher were provided in case the participants had any queries for clarification.

All the 60 participants were handed the participation invitation letter together with the informed statement consent. After reading and understanding the contents stated in the form, the participants signed the participant statement letter and returned to the researcher (Appendix B). The study was approved by FAM. The participants consented to be examined by a panel of medical doctors. All the 60 participants passed the medical examination (Appendix C). The participants selected for the study were all males, average age ± 37 years old. Average weight is ± 57 kilogrammes and average height is ± 151 centimetres. Most of the participants completed their secondary school education and are employed full time either in private sectors or the government. Officiating football matches were on part time basis as a hobby.

3.3 The Pre-Test

The FIFA Fitness Test comprising of repeated short sprints and repeated high intensity intermittent runs and Cooper's 12 minute test were conducted to all the 60 participants. All the three tests had to be conducted in a day. The pre-test was conducted on January 6, 2013 at 9.00 am at the 400 metre track, Kuala Lumpur Football Stadium (KLFS), Kuala Lumpur. The test was conducted by six qualified physical education lecturers and 20 physical education student teachers.

A list containing all the names of 60 participants arranged in alphabetical order was prepared. Numbers starting from 001 to 060 were written on pieces of paper and placed in a bowl (fishbowl method). The participants were invited to pick a piece of paper each. The participants were handed bibs corresponding to the numbers on the paper picked. If participant A picks up number 011, he would be handed bib number 011 and if participant B picks up number 018, he would be given bib 018.. This process would continue until all the participants were allocated bibs. A new list would be prepared for participants based on bib number 001 to 060.

3.3.1 Repeated Short Sprint Test

The participants would be assigned into eight groups. Two stations would be set up. In station one, a total of seven participants were assigned in a group and in station two eight participants in a group. The table below indicates the organization and administration of the test. As time was an important factor, the repeated short sprint test was conducted at two stations. The test would start at 9.00 am and expected to be completed by 10.00 am.

Table 3.1

Groups	Station One	Groups	Station Two	Time of Test	
1	Bibs 001 - 007	2	Bibs 008 – 015	9.00 – 9.15 am	
3	Bibs 016 - 022	4	Bibs 023 – 030	9.15- 9.30 am	
5	Bibs 031 - 037	6	Bibs 038 -045	9.30 – 9.45 am	
7	Bibs 046 - 053	8	Bibs 054 – 060	9.45 – 10.00 am	

Organisation and Administration of Repeated Short Sprint Test.

A data sheet for each group would be prepared to record the results (Appendix D). The test involves 6 x 40 metres sprints within 6.2 seconds with a recovery interval of 90 seconds after each sprint. The participants had to perform six repetitions in order to pass the test. The purpose of the test was to execute short sprints repeatedly to test the ability to recover between sprints and to test the physical demands of football referees. Equipment required for administering the test, the procedure and method of scoring are explained.

Figure 3.1 below indicates the lay out for Repeated Short Sprint Test.



Figure 3.1: Lay out plan for Repeated Short Sprint Test

The equipment required to conduct the test were 12 stop watches, measuring tape, marker cones and at least 50 metres of running track.

а	Equipment Required	Eight stop watches, measuring tape, marker cones and at least 50 metres of running track
b	Procedure	Marker cones are placed 40 metres apart to indicate the sprint distance.
		A start line is marked 1.5 metres before the

A start line is marked 1.5 metres before the timing gates.

Upon the signal, the referee runs 40 metres within 6.2 seconds. The sprint time is recorded The referee is given 90 seconds to return to the starting line for the next run.

Scoring The referee must complete all the six repetitions within the time allocated for each repetition and the interval given.

> If a referee falls or trips, he will be given another trial.

> If the referee does not achieve the standard in one out of six, he will be given one more trial after the 6th trial. If fails two trials, he fails the test.

3.3.2 Repeated High Intensity Intermittent Test

For the second test, the participants were assigned into three groups. 20 participants were assigned in a group. The table 3.2 below indicates the organization and administration of the test.

Table 3.2

Organization and Administration of Repeated High Intensity Intermittent Run.

Groups	Number	Participants	Time of Test
1	20	Bibs 011 – 020	10.15 – 10.40 am
2	20	Bibs 021 – 040	10.40 – 11.05 am
3	20	Bibs 041 – 060	11.05 – 11.40 am

с

A data sheet for each group was prepared to record the results (Appendix E). The second test conducted was the repeated high intensity intermittent test. The test started at 10.15 a.m. The test would be completed by 11.40 am. The test evaluates the referee's ability to perform repeated high intensity intermittent runs. Equipment required for the administration of the test, the procedures and method of scoring are explained below.



Figure 3.2: Lay out plan for Repeated High Intensity Intermittent Runs

a Equipment Required Two stop watches, flags, whistle, marker cones and 400 metres running track
b Procedure Upon the whistle, the referees must cover 150 metres in 30 seconds. They walk 50 metres in less than 35 seconds.
Upon hearing the next whistle, the referees run again

Upon hearing the next whistle, the referees run again 150 metres in 30 seconds, walk 50 metres in less than 35 seconds. These 2 repetitions equal one lap. The number of laps to be covered is ten. The referees run in groups not exceeding 20.

c Scoring The referee must arrive before the whistle in the 'walking area' that is marked by 4 cones (3 metres in front and 3 metres behind the 150 metre mark). If a referee fails to put one foot in the walking area in time, the observer signal and the referee must stop.

The referees may not leave the 'walking area' before the next whistle. Therefore the assistant test leaders are positioned at the start positions with a flag in their hands. Until the next whistle, they block the lane on the track by keeping the flag in a horizontal position. On the whistle, they quickly lower the flag so that the referees can start running. The assistant test leaders countdown (e.g. 15 seconds, 10 seconds, 5 seconds) so as to inform the referees of the precise timing. However, the flag only goes down on the whistle

3.3.3 Cooper's 12 minute run test

The participants would be given a lunch break until 5pm. The third test Cooper's 12 minute run test would be conducted at 5.15 pm at the same venue. The test would end at 6.10 pm. The participants would be assigned into three groups (as explained in second test). Each group consisted of 20 participants. A data sheet for each group would be prepared to record the results (Appendix F). The test evaluates the aerobic power of football referees in Malaysia using the Cooper's 12 minute run test. Table 3.3 indicates the details of organization and administration of Cooper's 12 minute run test.

Table 3.3

Groups	Number	Participants	Time of Test		
1	20	Bibs 011 – 020	5.15 – 5.35 pm		
2	20	Bibs 021 – 040	5.35 – 5.50 pm		
3	20	Bibs 041 – 060	5.50 – 6.10 pm		

Organization and administration of Cooper's 12 minute run test

The three tests must be completed in a day. This was the requirement set by FIFA. These tests must be administered on a 400 metre track. Participants are not allowed to use spikes or football boots. FIFA instruction stipulates that the participants are allowed to use only running shoes. The equipment required, procedure and method to measure the performance are mentioned below.

a Equipment Required 400 metre running track, marking cones, recording sheets, stop watches, whistle and measuring wheels.

b Procedure Marker cones are placed at set intervals of 50 metres around the track to aid in measuring the completed distances.

Participants run for 12 minutes and the distance covered is recorded. Walking is allowed, though the participants must be encouraged to push themselves as hard as they could. the test will blow the whistle indicating to stop. Measuring wheels would be used to determine the fraction of the last lap completed by each participant. This distance will then be added to the distance determined by the number of laps completed to give the total distance covered during the test.

c Scoring Distance covered by each participant in 12 minute run test is recorded in kilometers. The pass mark is completion of 2.6 kilometres in 12 minutes.

All the three tests were conducted by six physical education lecturers assisted by 20 trainee physical education teachers. Table 3.4 indicates the details and summary of the three tests which would be conducted, the requirements to pass and other relevant details.

Table 3.4

Test	Name of Test	Time Test Administered	Requirement to Pass the Test
1	Repeated Short Sprints	09.00 – 10.00 am	40 metre run in 6.2 seconds. 90 seconds to return to the starting point. Perform 6 repetitions within stipulated time.
2	Repeated High Intensity Intermittent Runs	10.15 – 11.40 am	Run 150 metres in 30 seconds. Walk 50 metres below 35 seconds (equals to one repetition). One lap equals to two repetitions. 10 laps within stipulated time to pass.
3	Cooper's 12 minute Run	05.15 – 06.10 am	Must complete a distance of 2.6 kilometres in 12 minutes.

The Details and Summary of the Three Tests.

3.4 Sampling

After the completion of Cooper's 12 minute run test. All the 60 participants were invited to assemble at the venue where the pre-tests were conducted to randomly assign them into three groups namely Experimental Group 1, Experimental Group 2 and Control Group. Each group consisted of 20 participants. The procedure executed to assign the participants is as follows, the 60 participants were asked to write down their names on the piece of paper provided and place it in a bowl (fishbowl method). The representative of the investigator blindfolded picks up the first paper from the bowl. The first drawn participant is assigned to Experimental Group 1. The next drawn name is assigned to Experimental Group 2 and the third to Control Group. This process is continued until all the 60 participants are assigned into three groups of 20 in each group.

After assigning the participants into three groups, the participants in the Control Group were requested to be present on March 17, 2013 at the same venue and time to take part in the post-test. The investigator informed the participants in Control Group that the post-test would be conducted at the same venue and the time of test would also be maintained. The investigator informed the participants of control group letters of reminder on the date, venue and time would be sent to them a week prior to the post-test. All the participants in the Control Group assured the investigator that they would be present to perform the post-test.

3.5 Procedure

The participants in Experimental Group 1 and 2 were given an introductory talk outlining the procedures employed in this study. The participants in Experimental Group 1 and Experimental Group 2 were informed that the objective of the study was to assess the effectiveness of 10 week training programme on physical parameters namely repeated short sprints, repeated high intensity intermittent runs and aerobic power in Malaysian football Referees. The participants were informed that the study would focus on individual performances in the pre-test, provide training for 10 weeks and determine if participants improved their performance in repeated short sprints, repeated high intensity intermittent runs and aerobic power based on the post-test results.

Further, the participants were informed that they should strive to complete six repetitions in repeated short sprints, 10 laps or 20 repetitions in repeated high intensity intermittent runs and 2.6 kilometres in Cooper's 12 minute run test within the stipulated time. They were reminded that it would be embarrassing to get an appointment and have to return home because the referee failed the fitness test. Getting an appointment and failing to fulfil the fitness requirement because of lack of fitness could very well mean that the referee may never get another opportunity. Finally, the participants were informed that referees who are fit and remain fit are bound to be presented with bountiful opportunities.

3.5.1 Experimental Group 1

The participants were requested to monitor and record three resting heart rate at different rested periods of the day over the course of a week and then hand over the readings to the investigator. The investigator upon receiving the readings would calculate the average and determine the resting heart rate.

The investigator explained to the participants the correct procedure to count the pulse. The participants could use a stop watch or a watch to count their pulse. They were taught how to locate and where to locate the pulse. The investigator demonstrated the location to find the pulse and explained that it had to be either in the radial artery on the wrist or at the carotid artery in the neck. The participants were advised to choose the spot that works best for them.

The investigator further advised the participants to use the correct finger to monitor the heart rate. The investigator reminded the participants not to use their thumbs as it has a light pulse and could create some confusion when counting the beats. It would be best to use the index finger and middle finger together. After finding the beat, count how many beats occur within 60 seconds. The shortcut to this method would be to count the number of beats in 10 seconds, and then to multiply that number by 6. This method gives a 60 second count. To participants who had problems finding the pulse or in the counting, they were asked to seek the help of a friend. After the resting heart rate had been determined, the Karvonen Formula would be used to determine the target heart rate (THR) training zone. The formula uses maximum and resting heart rate with the desired training intensity to get a target heart rate.

Target Heart Rate = (max HR - resting HR) × %Intensity) + resting HR

The participants in Experimental Group 1 were informed that they would be wearing **Polar FT 4 Unisex Heart Tate Monitor Watch when in training** (Appendix G). The monitor watches belonged to FAM and they were loaned to the participants. The participants were each given a watch. The investigator explained in details the functions in the watch and the procedures to follow. The participants were also given a copy of the manual to familiarise with the functions of the watch. As the watches belonged to FAM, the participants had to return the watches to the trainers after each training sessions.

The participants in Experimental Group 1 were also informed that the trainer would be giving feedback on their performances. This is to ascertain that the training protocols are properly adhered to. The participants would also be involved in brain storming discussion at the end of every training session to share or express their views.

As the main objective of the study was to investigate whether there would be significant difference in the performance of the three groups in the physical parameters after participating in a 10 week training programme, the participants in Experimental Group 1 pledged in writing to do their best during the training so that they would be able to pass the FIFA Fitness Test. An achievement of this status would definitely be a strong motivating factor for these referees and also to all aspiring referees.

The feedback that trainers provide could also be reminders to participants of their self-set goals. In this manner, trainers are creating an atmosphere where they prompt participants to remember the goals they set. These trainer-initiated reminders can help participants focus on their specific self-set goal and their action plan for goal achievement. Goal setting is becoming an increasingly popular motivational tool to use with participants to help increase performance (Weinberg & Gould, 2007).

Feedback is often provided to check the progress towards goal achievement. In a review of the effectiveness of feedback and goal setting, 17 out of the 18 reported studies found that the combination of both produced better performance gains than either one alone (Locke & Latham, 1990). Specifically, effective feedback enhances commitment, motivation, performance strategies and most importantly performance (Neubert, 1998). Effective feedback can indicate skill level, identify performance quality and help provide information on success of the task (Kluger & DeNisi, 1996).

Locke & Latham (2002) demonstrated that goal setting coupled with the use of feedback is more effective in encouraging performance than either goal setting or feedback alone. As a result of this finding, it was suggested that goals needed to be kept in constant focus.

Two physical education lecturers were appointed as trainers and six trainee teachers to assist them. Trainers and assistants were employed to make the participants more comfortable during the training sessions, to give participants confidence that they could achieve their goals, to keep formal records of what happened during each training session, in order to keep track of the workouts and to keep formal records of what happened during each training session. The participants assigned into Experimental Group 1 were requested to report to their trainers and their assistants at KLFA Stadium, Cheras at 5.30 pm three days a week for 10 weeks. The training days were Monday, Wednesday and Friday. During the off days, they were allowed to supervise football matches.

The rationale why a three day training programme lasting for 10 weeks were chosen is supported by the study by Gambetta (2007) indicated that significant improvement in speed, anaerobic and aerobic power in football referees occurred when they trained three days per week in 10 weeks. He reported that there was no significant difference in improvement between participants who exercised three consecutive days per week or subjects who exercised every alternate day. Rhea (2003) reported that for trained individuals a frequency of three days, one day rest between sessions is recommended. Other studies by Daussin et al. (2008); Helgerud et al. (2007); Musa et al. (2009) & Perry et al. (2008) reported that HIIT three days a week for 10 weeks produced the best results while limiting injuries to the participants.

The 10 week HIIT programme was formulated by three experts appointed by FAM based on the findings of Kubukeli, Noakes and Dennis (2002). In developing the programme, two prime considerations were taken into account. The first of these considerations is duration, intensity and frequency of the training programme and secondly, the recovery interval. Recovery from exercise training is an integral component of the overall training programme and is essential for optimal performance and improvement. If rate of recovery is improved, higher training volumes and intensities are possible without the detrimental effects of overtraining. While recovery from exercise is significant, trainers and coaches use different approaches for the recovery process for athletes (Bishop et al., 2007).

Jeffreys (2005) recovery include normalization of physiological functions, return to homeostasis restoration of energy stores and replenishment of cellular energy enzymes. Recovery may include an active component or passive component. According to Seiler (2005) short term recovery involves recovery between sets of a given exercise or between interval work bouts. Short-term recovery is the most common form of recovery in training.

For this study, the work interval has been set ranging from eight seconds to 15 minutes. The intensity of work interval was set to start off at the first week at 60% and 100 % of HR max towards the end of 10 weeks. As for the rest interval, a ratio of exercise to recovery was employed. A 1:1 ratio is 30 seconds of work followed by 30 seconds of rest or a ratio of 1:2, which is interpreted as 30 seconds of work followed by one minute rest. The appraisal of the programme was administered by three experts appointed by FAM (Appendices H, I and J)

HIIT and ST were mainly employed in the training programme to train the participants. The training programme predominantly uses running modes. Running modes were chosen because all individuals of different ages and body size can take part in the programme and feel comfortable. No specialized equipment is needed and it is a low cost intervention programme (Barlett et al., 2011).

HIIT can be described as an exercise session composed entirely of HIIT techniques or as a component of an exercise plan. HIIT exercise sessions generally consist of a warm up period then several repetitions of high intensity exercise separated by medium intensity exercise for recovery, then a cool down period. The high intensity exercise should be done at near maximum intensity. The medium exercise should be about 50% intensity. The number of repetitions and length of each depends on the exercise but may be as little as three repetitions with just 20 seconds of intense exercise. There is no specific formula to HIIT. The entire HIIT session may last between four and thirty minutes, Use of a monitor or timer is recommended to keep accurate time, target heart rate and, intensity (Laursen & Jenkins; 2002).

A study by Gibala (2009) on HIIT, three minutes of warm up followed by 60 seconds of intense exercise and 75 seconds of rest. These activities were performed ranging from eight to twelve sets three times a week. It was found the gains were similar to what would be expected from subjects who did steady state (50–70% VO_2max) training five times per week (Little et al., 2010).

Referees work full time and their physical training sessions often have to be arranged around work and family commitments, HIIT offers outstanding results without taking too much time (Gibala et al. 2012). Improvement in VO_{2 max}, aerobic anaerobic, muscle tone and performance could be seen in six HIIT sessions (Robert et al., 2013). HIIT is a time-efficient strategy to enhance whole body physiological functions (Jacobs et al 2013b). It is perceived to be enjoyable (Bartlett et al., 2011; Rakobowchuk et al., 2008).

3.5.2 Training Programme for Experimental Group 1.

The sequence of the training programme would be as follows:

3.5.2.1 Warm up for 10 -12 minutes

3.5.2.2 Stretching exercise for 10-15 minutes

- 3.5.2.3 Carry out the activity for the day as stated in the 10 week training programme.
- 3.5.2.4 Cooling down
- 3.5.2.5 Feed back to participants.

The participants report to the trainers and start off warming up on their own. Prior to starting any stretching or exercise programme, it is important to warm up your body and gradually increase your heart rate. A warm up could include a brisk walk or a light jog. This will start to distribute blood as needed to the working muscles. Warming up is how you are preparing your body for physical activity. After approximately 10-12 minutes of warming up it is safe to begin to stretch (Simic, Sarabon, & Markovic, 2013)

After the warm up session, the participants would carry out stretching exercises for about 10 to 15 minutes. The stretching exercises are shown in Appendix K. Stretching is important for many reasons and should be included in any physical fitness training programme. The benefits of stretching includes it improves flexibility, decreases risk of injury, reduces muscle tension, improves circulation, reduces anxiety, stress, and fatigue, improves muscle coordination, improves physical performance and enhances enjoyment of physical activities (Simic, Sarabon, & Markovic, 2013).

After the completion of stretching session, the participants would report to the trainers and the training programme scheduled for the day would be carried out (Appendix L). Intensity of training, rest intervals and repetitions for the day would be as in the programme. The 20 participants in Experimental Group 1 would be assigned into four groups namely Group A, B, C and D comprising of five participants in a group.

The grouping would be maintained from the start of the programme to the end (Appendix M). All the participants would be equipped with Polar FT 4 Unisex Heart Rate Monitor Watch to monitor, assist and for evaluation of their performance.

The average age of participants in Experimental Group 1 was 37 years old. The average resting heart rate was between 70 -72 and maximum heart rate 183. Based on these results, intensities starting with 50% to 100% were calculated and tabulated as guidelines for training using Karvonen Method (Appendix N).

Once the training session is completed, the participants would cool down. As for the cool down session the same type of activity as for warm up would be administered. The purpose of the cool down is to gradually lower the heart rate back to normal, and to redistribute the blood flow as needed throughout the body. Stretching upon completion of exercise increases flexibility and decreases possible muscle soreness. After the cooling down session a short feedback session will be held before the participants adjourned.

3.5.3 Experimental Group 2

In a dialogue session with the participants Experimental Group 2, the researcher found out that the participants trained every alternate day on their own. The participants do not possess or follow any training programme. There are no guidelines on the intensity and the majority had no idea of what is meant by the resting heart rate, the target heart rate (HR) training zone and the desired training intensity to get a target heart rate. The duration of the training also fluctuated between 30 minutes to 45 minutes. The investigator was informed that their training programme comprised of the following:

- a. Stretching exercise for about 10 minutes. The stretching are the exercises known to them.
- b. After stretching, their training starts. Their training usually consists of slow jog, walking, sideway running, running backwards and at times faster jogging. The investigator was also informed they stopped to rest whenever they feel they are tired. Training ends when they thought was enough for the day.
- c. Sometimes, they were involved in minor games. They play football 3 against 3 or four against four using mini goal post for about 15 to 20 minutes after which they adjourned.
- d. The participants in Experimental Group 2 never performed cooling down activities.

The investigator found that their training programme comprised of only jogging and occasionally involved in minor games. It was also found that they had no idea of methods of training, types of training, intensity, duration or frequency of training. The Experimental Group 2 was invited to train at Institut Perguruan Ilmu Khas, Kuala Lumpur on Monday, Wednesday and Friday staring at 5.30 p.m. 400 metre track was booked for the whole duration of 10 weeks and participants use the facilities to train using their own modalities without interference from the trainers. The duty of the trainers would be to keep record of attendance and observe the type of training the participants in Experimental Group 2 performed.

The investigator informed the participants in Experimental Group 2 that the post-test would be conducted on March 17, 2013 at the same venue and the time of test would also be maintained. The investigator informed the participants of Experimental Group 2 letters of reminder on the date, venue and time would be sent to them a week prior to the post-test. All the participants in the Experimental Group 2 assured the investigator that they would be present to perform the post-test.

3.5.4 Control Group

After assigning the participants into three groups, the participants in the Control Group were requested to be present on March 17, 2013. The investigator informed the participants in Control Group that the post-test would be conducted at the same venue and the time of test would also be maintained. The investigator informed the participants of control group letters of reminder on the date, venue and time would be sent to them a week prior to the post-test. All the participants in the Control Group assured the investigator that they would be present to perform the post-test.

3.6 Post-Test

The post-test for the three groups would be administered after 10 weeks. It would be administered on March 17, 2013 at the same venue, time and by the same officials. The post-test would be conducted using the same procedure as the pre-test. The participants would be tested on repeated short sprints, repeated high intensity intermittent runs and aerobic power. Experimental Group 1 would be exposed to the experimental treatment for 10 weeks. Experimental Group 2 would be involved in their own training programme for 10 weeks. The Control Group would be left on their own. At the end of 10 weeks, the researcher would investigate whether there is a significant difference in the performance of repeated short sprints, high intensity intermittent runs and aerobic power among the referees in Malaysia.

3.7 Statistical Procedures

The study aims to determine whether there is a significant difference in the performance of repeated short sprints, repeated high intermittent runs and Cooper's 12 minute run test after 10 weeks. A mixed between-within subject analysis known as split-plot ANOVA (SPANOVA) would be conducted with an alpha of 0.05.

For the first three research questions stated below, the investigator would administer the within subject analysis for each group separately to determine whether there is a statistical significant difference in the performance in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results.

- 3.7.1 Is there a statistical significant difference in the performance of Experimental Group 1 in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results?
- 3.7.2 Is there a statistical significant difference in the performance of Experimental Group 2 in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results?
 - 3.7.3 Is there a statistical significant difference in the performance of Control Group in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results?

For the following research questions the investigator would administer a mixed between-within subject analysis known as split-plot ANOVA (SPANOVA) with an alpha value of .05. This would determine whether there was a significant difference in the performance of the three groups in repeated short sprints, repeated high intensity intermittent runs and aerobic power after 10 weeks.

- 3.7.4 Is there a statistical difference in the performance of the three groups in repeated short sprints after participating in a 10 Week Training Programme?
- 3.7.5 Is there a statistical significant difference in the performances of the three groups in repeated high intensity intermittent runs after participating in a 10 Week Training Programme?

3.7.6 Is there a statistical significant difference in the performances of the three groups in aerobic power after participating in a 10 Week Training Programme?

Further, to determine whether there would be a significant difference between pre-test and post-test scores as a whole and a significant effect on the treatment for the three groups, Multivariate Tests using Pillai's Trace would be administered.

In order to investigate the significant difference between groups, Tukey Pair Wise Comparison between groups would be administered.

CHAPTER 4: RESULTS

This chapter presents the results of the study. The demographic characteristics of the participants are provided, followed by a presentation of each research question and a review of the statistical assumptions for each analysis. The findings for each research question are then discussed including an evaluation and interpretation of the results. The chapter concludes with a summary.

Firstly, the study aims to investigate the performance of Experimental Group 1, Experimental Group 2 and Control Group separately in the physical parameters namely repeated short sprints, repeated high intensity intermittent runs and aerobic power based on pre-test and post-test results of each group to determine whether there exist a significant difference in performance within the group.

Secondly, the study aims to compare between group the significance of a 10 Week Training Programme on physical parameters namely repeated short sprints, repeated high intensity intermittent runs and aerobic power among the three groups of football referees in Malaysia.

The total population of referees in Malaysia numbered 120 residing all over Malaysia. For this study sixty male participants residing in Selangor and Kuala Lumpur average age ± 37 years old met the inclusion criteria and agreed to participate. None of the participants selected withdrew from the study.

SPANOVA, also referred to as mixed within-group between-group ANOVA, would be conducted to assess the results of the intervention for all research questions. Data analyses would be performed using SPSS statistical software. All tests were two tailed with an alpha significance level of .05.

For the first three research questions, the investigator administered the within subject analysis for each group separately to determine whether there was a statistical significant difference in the performance in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results.

For the research questions four to six, the investigator administered a mixed between-within subject analysis known as split-plot ANOVA (SPANOVA) with an alpha value of .05. This would determine whether there was a significant difference in the performance of the three groups in repeated short sprints, repeated high intensity intermittent runs and aerobic power after 10 weeks.

Further, to determine whether there would be a significant difference between pre-test and post-test scores as a whole and a significant effect on the treatment for the three groups, Multivariate Tests using Pillai's Trace was be administered. In order to investigate the significant difference between groups, Tukey Pair Wise Comparison between groups would be administered. 4.1 Is there a statistical significant difference in the performance of Experimental Group 1 in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results?

The performances of all the participants in Experimental Group 1 in repeated short sprints were analyzed based on pre-test and post-test results. The results indicated that there was a statistical significant difference in performance of Experimental Group 1 in repeated short sprints in comparison of pre-test (M=3.25 SD= 0.64) and post-test results (M=5.9, SD=0.31); t (19) = 20.2, p<0.05.

As for the performances of participants in Experimental Group 1 in repeated high intensity intermittent runs, the results indicated that there was a statistical significant difference in comparison of pre-test (M=4.30, SD=1.13) and post-test results (M=9.80, SD =0.41); t (19) = 22.4, p<0.05.

Further, the results of performances by participants in Experimental Group 1 in aerobic power indicated that there was a statistical significant difference in comparison of pre-test (M=2.18, SD=0.13) and post-test results (M=2.71, SD=0.06); t (19) = 19.4, p<0.05

The results in Table 4.1 indicated that there was a statistical significant difference in the performance of Experimental Group 1 in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results.

Table 4.1

Test		Mean	SD	t	Sig
Repeated Short Sprints	Pre-Test	3.25	0.64	20.2	p<0.05
	Post-Test	5.90	0.31		
Papaetad High Intensity Intermittent Pupe	Pre-Test	4.30	1.13	22.4	n <0.05
Repeated Figh Intensity Interimitent Runs	Post-Test	9.80	0.41	22.4	p<0.05
A anakia Davuan	Pre-Test	2.18	0.13	10.4	n <0.05
Aerodic Power	Post-Test	2.71	0.06	19.4	p<0.05

Summary of pre-test and post-test result of Experimental Group 1 in repeated short sprints, repeated high intensity intermittent runs and aerobic power

4.2 Is there a statistical significant difference in the performance of Experimental Group 2 in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results?

The performances of all the participants in Experimental Group 2 in repeated short sprints were analyzed based on pre-test and post-test results. The results indicated that there was a statistical significant difference in performance of Experimental Group 2 in repeated short sprints in comparison of pre-test (M=3.20 SD= 0.62) and post-test results (M=3.70, SD=0.66); t (19) = 3.3, p<0.05.

As for the performances of participants in Experimental Group 2 in repeated high intensity intermittent runs, the results indicated that there was a statistical significant difference in comparison of pre-test (M=3.80, SD=1.01) and post-test results (M=6.40, SD = 2.06); t (19) = 8.6, p<0.05

Further, the results of performances by participants in Experimental Group 2 in aerobic power indicated that there was a statistical significant difference in comparison of pre-test (M=2.16, SD=0.13) and post-test results (M=2.26, SD=0.13); t (19) = 5.6, p< 0.05

The results in Table 4.2 indicated that there was a statistical significant difference in the performance of Experimental Group 2 in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results..
Table 4.2

Test		Mean	SD	t	Sig
Papaoted Short Sprints	Pre-Test	3.20	0.62	33	n<0.05
Repeated Short Sprints	Post-Test	3.70	0.66	5.5	p<0.05
	Pre-Test	3.80	1.01		
Repeated High Intensity Intermittent Runs	Post-Test	6.40	2.06	8.6	p<0.05
S	Pre-Test	2.16	0.13		
Aerobic Power	Post-Test	2.26	0.13	5.6	p<0.05

Summary of pre-test and post-test result of Experimental Group 2 in repeated short sprints, repeated high intensity intermittent runs and aerobic power

4.3 Is there a statistical significant difference in the performance of Control Group in repeated short sprints, repeated high intensity intermittent runs and aerobic power in comparison of pre-test and post-test results?

The performances of all the participants in Control Group in repeated short sprints were analyzed based on pre-test and post-test results. The results indicated that there was no statistical significant difference in performance of Control Group in repeated short sprints in comparison of pre-test (M=3.05 SD=0.69) and post-test results (M=3.20, SD=0.52); t (19) = 0.4, p>0.05.

As for the performances of participants in Control Group in repeated high intensity intermittent runs, the results indicated that there was a statistical significant difference in comparison of pre-test (M=4.40, SD=1.05) and post-test results (M=4.60, SD = 1.05); t (19) = 2.18, p<0.05.

Further, the results of performances by participants in Control Group in aerobic power indicated that there was no statistical significant difference in comparison of pretest (M=2.12, SD=0.13) and post-test results (M=2.13, SD=0.14); t (19) = 0.7, p>0.05.

The results in Table 4.3 indicated that there was a statistical significant difference in the performance of Control Group in repeated high intensity intermittent runs but there was no statistical significant difference in repeated short sprints and aerobic power in comparison of pre-test and post-test results.

Table 4.3

Summary of pre-test and post-test result of Control Group in repeated short sprints, repeated high intensity intermittent runs and aerobic power

Test		Mean	SD	t	Sig
	Pre-Test	3.05	0.69	0	
Repeated Short Sprints				0.4	p>0.05
	Post-Test	3.20	0.52		
Repeated High Intensity Intermittent Runs	Pre-Test	4.40	1.05	2.18	p<0.05
Repeated High Intensity Intermittent Runs	Post-Test	4.60	1.05		Ĩ
	Pre-Test	2.13	0.14		
Aerobic Power				0.7	p>0.05
	Post-Test	2.12	0.13		

4.4 Is there a statistical significant difference in the performances of the three groups in repeated short sprints after participating in a 10 Week Training Programme?

The investigator administered a mixed between-within subject analysis known as split-plot ANOVA (SPANOVA) with an alpha value of .05. This would determine whether there was a significant difference in the performance of the three groups in repeated short sprints after 10 weeks.

Further, to determine whether there was a significant difference between pre-test and post-test scores as a whole and a significant effect on the treatment for the three groups, Multivariate Tests using Pillai's Trace would be administered. In order to investigate the significant difference between groups, Tukey Pair Wise Comparison between groups would be administered.

The performance in repeated short sprints by the three groups in pre-test and post-test are indicated in Table 4.4. The table provides descriptive statistics for the three groups in pre-test test and post-test means (M), standard deviation (SD) and number of participants in each group.

Table: 4.4

		Pre-Test	Post-Test		
Group	Ν	Mean	SD	Mean	SD
Experimental Group 1	20	3.25	0.64	5.90	0.31
Experimental Group 2	20	3.20	0.62	3.70	0.66
Control Group	20	3.05	0.69	3.20	0.52
Total	60	3.17	0.64	4.26	1.29

Comparison of Pre-Test and Post-Test Means and Standard Deviation of Three Groups in Repeated Short Sprints

Table 4.4 displays the means and the standard deviations of the three groups in the pre-test. Experimental Group 1 (M=3.25, SD=0.64), Experimental Group 2 (M=3.20, SD=0.62) and Control Group (M=3.05, SD=0.69). The direction of effect showed the mean and the standard deviation for the three groups are clustered closely. The Total Group means and standard deviation are (M=3.17, SD=0.64)

The post-test results indicate Experimental Group 1 (M=5.90, SD=0.31), Experimental Group 2 (M=3.70, SD=0.66) and Control Group (M=3.20, SD=0.52) The Total Group means and standard deviation are (M=4.26, SD=1.29). Figure 4.1 indicates the pre-test and post-test means for the three groups based on the number of repetitions in repeated short sprints.





To determine whether there was a significant difference in performance of repeated short sprints by the three groups in pre-test and post-test a mixed betweenwithin subject analysis known as split-plot ANOVA (SPANOVA) was administered with an alpha of 0.05. The results are indicated in Table 4.5

Table 4.5

SPANOVA tests of between groups in repeated short sprints for pre-test and post-test

Pre-Test	Sum of Squares	df	Mean Square	F	Sig
Between Groups	0.43	2	0.22		
Within Groups	23.90	57	0.42	.517	.599
			NO		
Post-Test	Sum of Squares	df	Mean Square	F	Sig
					215
Between Groups	82.53	2	41.27		
Between Groups	82.53	2	41.27	154.75	.001

Table 4.5 pre-test results indicated that there was no significant difference among the three groups in repeated short sprints [F (2, 57) = .517, p > .05]. After undergoing a 10 week training programme, the post- test results indicated that there was a significant difference among the three groups in the performance of repeated short sprints [F (2, 57) = 154.75, p<0.05].

To determine whether there was a significant difference between pre-test and post-test scores as a whole and to determine if there was a significant effect on the treatment for the three groups, Multivariate Tests using Pillai's Trace was administered. Table 4.6 indicates the results of analysis.

Table 4.6

Multivariate Tests^a Using Pillai's Trace in pre-test and post-test for repeated short sprints

Effect	Value	F	Hypothesis df	Error df	Sig
Pillai's Trace	0.783	205.881 ^b	1.000	57.000	.001
Measure* Group	Value	F	Hypothesis df	Error df	Sig
Pillai's Trace	0.785	103.993 ^b	2.000	57.000	.001

a. Design: Intercept + group

b. Within Subjects Design: measure Exact statistics

The analysis in Table 4.6, Pillai's Trace [F (1, 57) = 205.88, p < 0.05] indicated that there was a significant difference between pre-test and post-test scores as a whole. It showed that the programme had significant effect on repeated short sprints after treatment. There was also a significant interaction effect of the treatment for the three groups. [F (2, 57) = 103.93, p < 0.05] Tukey Pair Wise Comparison was administered to investigate the significant difference between groups. Table 4.7 displays the results of Tukey Pair Wise Comparison among groups for the three groups in repeated short sprints.

Table 4.7

Tukey Pair Wise Comparison in pre-test and post-test for the three groups in repeated short sprints.

(I)group	(J) group	Mean Difference (I-J)	Std Error	Sig ^b
Experimental Gr.1	Experimental Gr.2	1.125*	.160	.001
	Control	1.450*	.160	.001
Experimental Gr.2	Experimental Gr.1	-1.125	.160	.001
	Control	0.325*	.160	.046
Control	Experimental Gr.1	-1.450	.160	.001
	Experimental Gr.2	-0.325	.160	.046

Based on estimated marginal means

* The mean difference is significant at the 0.05 level.

^{b.} Adjustment for multiple comparisons: Least significant Difference (Equivalent to no adjustment

Table 4.7 displays the performance comparison in repeated short sprints between Experimental Group 1 and Experimental Group 2. The results indicated there is a significant difference in the performance of the two groups. The performance of Experimental Group 1 was better than the performance of Experimental Group 2 in repeated short sprints.

The performance comparison in repeated short sprints between Experimental Group 1 and Control Group was administered, the results indicated that there is a significant difference in the performance of the two groups. The results indicated that that the performance of Experimental Group 1 was better than the performance of Experimental Group 2.

The performance comparison in repeated short sprints between Experimental Group 2 and Control Group was administered; the results indicated that there is a significant difference in the performance of the two groups. The performance of Experimental Group 2 was better than the performance of Control Group in repeated short sprints. The results indicated the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group 2 and Control Group in repeated short sprints.

The results indicate that there is a statistical significant difference in the performances of the three groups in repeated short sprints after participating in a 10 Week Training Programme [F (2, 57) = 154.75, p<0.05].

Pillai's Trace [F (1, 57) = 205.88, p < 0.05] indicated that there was a significant difference between pre-test and post-test scores as a whole. There was also a significant interaction effect of the treatment for the three groups [F (2, 57) = 103.93, p < 0.05]. It showed that the programme had significant effect on repeated short sprints after treatment.

The results of Tukey Pair Wise Comparison displayed that statistically significant differences existed between Experimental Group 1 and Experimental Group 2, (mean difference 1.125). Experimental Group 1 and Control Group (mean difference 1.450) and significance difference existed between Experimental Group 2 and Control Group (mean difference 0.325). The result of statistical analysis confirmed that the Experimental Group 1 showed the best performance and the Control Group the poorest. Based on the analysis it can be concluded that the training method used by Experimental Group 1 was better than the training method used by Experimental Group 2.

The results indicated that a 10 week training programme had an effect to improve number of repeated short sprints. Specifically, our results suggested that when referees trained with a specific training programme for 10 weeks, the required number of six repetitions to pass the FIFA Tests could be achieved. By participating in jogging activities, minor games or officiating football matches did not appear to significantly increase the performance of repeated short sprints. 4.5 Is there a statistical significant difference in the performances of the three groups in repeated high intensity intermittent runs after participating in a 10 Week Training Programme?

The investigator administered a mixed between-within subject analysis known as split-plot ANOVA (SPANOVA) with an alpha value of .05. This determined whether there was a significant difference in the performance of the three groups in repeated high intensity intermittent runs after 10 weeks.

Further, to determine whether there was a significant difference between pre-test and post-test scores as a whole and a significant effect on the treatment for the three groups, Multivariate Tests using Pillai's Trace was administered. In order to investigate the significant difference between groups, Tukey Pair Wise Comparison between groups was administered.

The performance in repeated high intensity intermittent runs by the three groups in pre-test and post-test are indicated in Table 4.8.. The table provides descriptive statistics for the three groups in pre-test test and post-test means (M), standard deviation (SD) and number of participants in each group.

Table: 4.8

		Pre-Test	Post-Test		
Group	Ν	Mean	SD	Mean	SD
Experimental Group 1	20	4.30	1.13	9.80	0.41
Experimental Group 2	20	3.80	1.01	6.40	2.06
Control Group	20	4.40	1.05	4.60	1.05
Total	60	4.17	1.08	6.93	2.55

Comparison of Pre-Test and Post-Test Means and Standard Deviation of Three Groups in Repeated High Intensity Intermittent Run

Table 4.8 displays the means and the standard deviations of the three groups in the pre-test. Experimental Group 1 (M=4.30, SD=1.13), Experimental Group 2 (M=3.80, SD=1.01) and Control Group (M=4.40, SD=1.05). The direction of effect showed the mean and the standard deviation for the three groups are clustered closely. The Total Group means and standard deviation are (M=4.17, SD=1.08)

The post-test results indicate Experimental Group 1 (M=9.80, SD=0.41), Experimental Group 2 (M=6.40, SD=2.06) and Control Group (M=4.60, SD=1.05). The Total Group means and standard deviation are (M=6.93, SD=2.55). Figure 4.2 indicates the pre-test and post-test means for the three groups based on repetitions performed in repeated high intensity intermittent runs.



Figure 4.2: Estimated Marginal Means of One Way Pre Test and Post Test by Groups in repeated high intensity intermittent runs

To determine whether there was a significant difference in performance of repeated high intensity intermittent runs by the three groups in pre-test and post-test a mixed between-within subject analysis known as split-plot ANOVA (SPANOVA) was administered with an alpha of 0.05. The results are indicated in Table 4.9

Table 4.9

SPANOVA Tests of Between Groups in repeated high intensity intermittent runs for pre-test and post-test

Pre-Test	Sum of Squares	df	Mean Square	F	Sig
Between Groups	4.13	2	2.07		
				1.84	.169
Within Groups	64.20	57	1.13		
Post-Test	Sum of Squares	df	Mean Square	F	Sig
Between Groups	278.93	2	139.47		
				75.86	.001
Within Groups	104.80	57	1.84		

Table 4.9 pre-test results indicated that there was no significant difference among the three groups in repeated high intensity intermittent runs [F (2, 57) = 1.84, p >.05]. After undergoing a 10 week training programme, the post- test results indicated that there was a significant difference among the three groups in the performance of repeated high intensity intermittent runs [F (2, 57) =75.86, p<0.05].

To determine whether there was a significant difference between pre-test and post-test scores as a whole and to determine if there was a significant effect on the treatment for the three groups, Multivariate Tests using Pillai's Trace was administered. Table 4.10 indicates the results of analysis.

Table 4.10

Multivariate Tests^a Using Pillai's Trace in pre-test and post-test for repeated high intensity intermittent runs

Effect	Value	F	Hypothesis df	Error df	Sig
Pillai's Trace	0.883	429.15 ^b	1.000	57.000	.001
Measure* Group	Value	F	Hypothesis df	Error df	Sig
Pillai's Trace	0.822	131.63 ^b	2.000	57.000	.001

a. Design: intercept + group

b. Within Subjects Design: Measure Exact Statisticst

The analysis in Table 4.10, Pillai's Trace [F (1, 57) = 429.15, p < 0.05] indicated that there was a significant difference between pre-test and post-test scores as a whole. It showed that the programme had significant effect on repeated high intensity intermittent runs after treatment. There was also a significant interaction effect of the treatment for the three groups. [F (2, 57) = 131.63, p < 0.05] Tukey Pair Wise Comparison between groups was administered to investigate the significant difference between groups. Table 4.11 displays the results of Tukey Pair Wise Comparison between groups for the three groups in repeated high intensity intermittent runs.

Table 4.11 displays the performance comparison in repeated high intensity intermittent runs between Experimental Group 1 and Experimental Group 2. The results indicate there is a significant difference in the performance of the two groups. The performance of Experimental Group 1 was better than the performance of Experimental Group 2 in repeated high intensity intermittent runs.

Table 4.11

(I)group	(J) group	Mean Difference (I-J)	Std Error	Sig ^b
Experimental Gr.1	Experimental Gr.2	1.950*	.349	.001
	Control	2550*	.349	.001
Experimental Gr.2	Experimental Gr.1	-1.950	.349	.001
	Control	0.600*	.349	.091
Control	Experimental Gr 1	-2 550	349	001
control		2.550		.001
	Experimental Gr.2	-0.600	.349	.091

Tukey Pair Wise Comparison in pre-test and post-test for the three groups in repeated high intensity intermittent runs.

Based on estimated marginal means

* The mean difference is significant at the 0.05 level.

b. Adjustment for multiple comparisons: Least significant Difference (Equivalent to no adjustment.

The performance comparison in repeated high intensity intermittent runs between Experimental Group 1 and Control Group were administered, the results indicated that there was a significant difference in the performance of the two groups. The results indicated that that the performance of Experimental Group 1 was better than the performance of Control Group.

The performance comparison in repeated high intensity runs between Experimental Group 2 and Control Group were administered, the results indicated that there was no significant difference in the performance of the two groups. The performance of Experimental Group 2 was better than the performance of Control Group in repeated high intensity intermittent runs. The results indicated the performance of Experimental Group 2 was better than the performance of Control Group. The performance of Experimental Group 2 was better than the performance of Control Group. The performance of Experimental Group 1 was better than the performance of Experimental Group 2 and the Control Group in repeated high intensity intermittent runs.

The results indicate that there was a statistical significant difference in the performances of the three groups in repeated high intensity intermittent runs after participating in a 10 Week Training Programme [F (2, 57) = 75.86, p<0.05].

Pillai's Trace [F (1, 57) = 429.15, p < 0.05] indicated that there was a significant difference between pre-test and post-test scores as a whole. There was also a significant interaction effect of treatment for the three groups [F (2, 57) = 131.63, p < 0.05]. It showed that the programme had a significant effect on repeated high intensity intermittent runs after treatment.

The results of Tukey Pair Wise Comparison displayed that statistically significant differences existed between Experimental Group 1 and Experimental Group 2, (mean difference 1.1950). Experimental Group 1 and Control Group (mean difference 2.550) and there is a significant difference in the performance between Experimental Group 2 and Control Group (mean difference 0.600). The result of statistical analysis confirmed the Experimental Group 1 showed the best performance and the Control Group the poorest. Based on the results it can be concluded that the training method used by Experimental Group 1 was better than the training method used by Experimental Group 2.

The results indicated that a 10 week training programme had an effect to improve number of repeated high intensity intermittent runs. Specifically, our results suggested that when referees trained with a specific training programme for 10 weeks, the required number of 10 repetitions to pass the FIFA Tests could be achieved. However, it should be noted that serious training had to be carried out in order to see an effect. By participating in jogging activities, minor games or officiating football matches did not appear to significantly increase the performance of repeated high intensity intermittent runs. 4.6 Is there a statistical significant difference in the performances of the three groups in aerobic power after participating in a 10 Week Training Programme?

The investigator administered a mixed between-within subject analysis known as split-plot ANOVA (SPANOVA) with an alpha value of .05. This determined whether there was a significant difference in the performance of the three groups in aerobic power after 10 weeks.

Further, to determine whether there would be a significant difference between pre-test and post-test scores as a whole and a significant effect on the treatment for the three groups, Multivariate Tests using Pillai's Trace were administered. In order to investigate the significant difference between groups, Tukey Pair Wise Comparison between groups would be administered.

The performance in aerobic power by the three groups in pre-test and post-test are indicated in Table 4.12. The table provides descriptive statistics for the three groups in pre-test test and post-test means (M), standard deviation (SD) and number of participants in each group.

Table: 4.12

		Pre-	-Test	Post	-Test
Group	Ν	Mean	SD	Mean	SD
Experimental Group 1	20	2.18	0.131	2.71	0.055
Experimental Group 2	20	2.16	0.127	2.26	0.131
Control Group	20	2.12	0.130	2.13	0.138
Total	60	2.15	0.130	2.37	0.275

Comparison of Pre-Test and Post-Test Means and Standard Deviation of Three Groups in Aerobic Power

Table 4.12 displays the means and the standard deviations of the three groups in the pre-test. Experimental Group 1 (M=2.18, SD=0.131), Experimental Group 2 (M=2.16, SD=0.127) and Control Group (M=2.12, SD=0.130). The direction of effect showed the mean and the standard deviation for the three groups are clustered closely. The Total Group means and standard deviation are (M=2.15, SD=0.130) The post-test results indicate Experimental Group 1 (M=2.71, SD=0.055), Experimental Group 2 (M=2.26, SD=0.131) and Control Group (M=2.13, SD=0.138). The Total Group means and standard deviation are (M=2.37, SD=0.275).

Figure 4.3 indicates the pre-test and post-test means in aerobic power for the three groups based on the distance in kilometres in Cooper 12 minute run test.



Figure 4.3 Estimated Marginal Means of One Way Pre Test and Post Test by Group for aerobic power

To determine whether there was a significant difference in performance of Cooper 12 minute run test by the three groups in pre-test and post-test a mixed betweenwithin subject analysis known as split-plot ANOVA (SPANOVA) was administered with an alpha of 0.05. The results are indicated in Table 4.13

Table 4.13

Pre-Test	Sum of Squares	df	Mean Square	F	Sig
Between Groups	0.047	2	0.023		
				1.390	0.257
Within Groups	0.955	57	0.017		
	Ctr.				
Post-Test	Sum of Squares	df	Mean Square	F	Sig
Between Groups	3.705	2	1.853		
				141.18	0.001
Within Groups	0.748	57	0.13		

SPANOVA Tests of Between Groups in aerobic power for pre-test and post-test

Table 4.13 pre-test results indicated that there was no significant difference among the three groups in aerobic power [F (2, 57) = 1.39, p >.05]. After undergoing a 10 week training programme, the post- test results indicated that there was a significant difference among the three groups in the performance of Cooper 12 minute run test [F (2, 57) =141.18, p<0.05].

To determine whether there was a significant difference between pre-test and post-test scores as a whole and to determine if there was a significant effect on the treatment for the three groups, Multivariate Tests using Pillai's Trace was administered. Table 4.14 indicates the results of analysis.

Table 4.14

Multivariate Tests^a Using Pillai's Trace in pre-test and post-test for 12 minute run test

Effect	Value	F	Hypothesis df	Error df	Sig
Pillai's Trace	0.838	295.922 ^b	1.000	57.000	.001
Measure* Group	Value	F	Hypothesis df	Error df	Sig
Pillai's Trace	0.852	164.174 ^b	2.000	57.000	.001

- a. Design: Intercept + group
- b. Within Subjects Design: measure Exact statistics

The analysis in Table 4.14, Pillai's Trace [F (1, 57) = 295.92, p < 0.05] indicated that there was a significant difference between pre-test and post-test scores as a whole. It showed that the programme had significant effect on aerobic power after treatment. There was also a significant interaction effect of the treatment for the three groups. [F (2, 57) = 164.17, p < 0.05]

Table 4.15

Between Group Comparisons using Tukey Pair Wise for Cooper 12 minute run test

(I)group	(J) group	Mean Difference (I-J)	Std Error	Sig ^b
Experimental Gr.1	Experimental Gr.2	0.2375*	0.03556	.001
	Control	03238*	0.03556	.001
Experimental Gr.2	Experimental Gr.1	-0.2375	0.03556	.001
		0.00.00*	0.02556	0.40
	Control	0.0863*	0.03556	.048
		0.2220	0.02556	001
Control	Experimental Gr.1	-0.3238	0.03556	.001
	Experimental Gr 2	0.0863	0.03556	048
	Experimental OF.2	-0.0603	0.05550	.040

Based on estimated marginal means

- * The mean difference is significant at the 0.05 level.
- **b.** Adjustment for multiple comparisons: Least significant Difference (Equivalent to no adjustment

Table 4.15 displays the performance comparison in aerobic power between Experimental Group 1 and Experimental Group 2. The results indicate there is a significant difference in the performance of the two groups. The performance of Experimental Group 1 was better than the performance of Experimental Group 2 in Cooper 12 minute run test.

The performance comparison in Cooper 12 minute test between Experimental Group 1 and Control Group was administered, the results indicated that there was a significant difference in the performance of the two groups. The results indicated that that the performance of Experimental Group 1 was better than the performance of Control Group.

The performance comparison in Cooper 12 minute run test between Experimental Group 2 and Control Group was administered, the results indicated that there is a significant difference in the performance of the two groups. The performance of Experimental Group 2 was better than the performance of Control Group in Cooper 12 minute run tests. The results indicated the performance of Experimental Group 2 was better than the performance of Control Group. The performance of Experimental Group 1 was better than the performance of Experimental Group 1 was better than the performance of Experimental Group in Cooper 12 minute run test.

The results indicate that there is a statistical significant difference in the performances of the three groups in Cooper 12 minute test after participating in a 10 Week Training Programme [F (2, 57) = 141.18, p<0.05].

Pillai's Trace [F (1, 57) = 295.92, p < 0.05] indicated that there was a significant difference between pre-test and post-test scores as a whole. There was also a significant interaction effect of treatment for the three groups [F (2, 57) = 164.17, p < 0.05]. It showed that the programme had significant effect on Aerobic power after treatment.

`The results of Tukey Pair Wise Comparison displayed that statistically significant differences existed between Experimental Group 1 and Experimental Group 2, (mean difference 0.2375). Experimental Group 1 and Control Group (mean difference 0.3238) and there was a significant difference in the performance between Experimental Group 2 and Control Group (mean difference 0.0863). The result of statistical analysis confirmed the Experimental Group 1 showed the best performance and the Control Group the poorest. Based on the results it can be concluded that the training method used by Experimental Group 1 was better than the training method used by Experimental Group 2.

The results indicated that a 10 week training programme had an effect to improve the distance covered in Cooper 12 minute run test. Specifically, our results suggested that when referees trained with a specific training programme for 10 weeks, the required distance of 2.6 kilometres to pass the FIFA Tests could be achieved. However, it should be noted that serious training had to be carried out in order to see an effect. By participating in jogging activities, minor games or officiating football matches did not appear to significantly improve aerobic power.

CHAPTER 5: DISCUSSION, CONCLUSION AND RECOMMENDATION

This chapter presents discussion and conclusions of the study. This final chapter also makes recommendations for future research.

This study was an experimental research design which involved pre-test and post-test to evaluate the performance of football referees in physical parameters namely repeated short sprints, repeated high intensity intermittent runs using the FIFA Fitness Test. The design of this study focused upon individual performances in the pre- test, providing training for 10 weeks and to determine if the participants could pass the FIFA Fitness Test for football referees as a result of experimental treatment.

The pre-test was conducted on January 6, 2013 at 9.00 am at the 400 metre track, Kuala Lumpur Football Stadium (KLFS), Kuala Lumpur. The test was conducted by six qualified physical education lecturers and 20 physical education student teachers. After the pre-test the participants were randomly assigned into three groups namely Experimental Group 1, Experimental Group 2 and Control Group using the fishbowl method.

The pre-test results in repeated short sprints, repeated high intensity intermittent runs and aerobic power indicated that none of the participants passed the FIFA Fitness Test as the participants did not meet the requirements set by FIFA. In order to pass the repeated short sprint test, FIFA made it compulsory for referees to complete 40 metres x 6 repetitions within the stipulated time. To pass the repeated high intensity intermittent run test, the participants had to complete 150 metres x 20 repetitions on a 400 metre track within the stipulated time. The minimum requirement to pass the Cooper 12 minute run was 2.6 kilometres. The referees must pass all the three tests. It was found that football referees in Malaysia trained on their own to develop their physical fitness. There has been no specific training programme designed to improve the fitness. The referees work full-time and their physical training sessions often have to be arranged around work and family commitments.

Guillen & Feltz (2011) reported that aerobic, anaerobic power and speed are essential components for referees to pass the FIFA Fitness Test. Referees are required to do FIFA Fitness Tests at a short notice before a tournament. It will certainly be embarrassing to get an appointment and have to return home because the referee failed the fitness tests. Getting an appointment and failing to fulfill it because of lack of fitness could very well mean that the referee may never get another opportunity. Referees who are fit and remain fit are bound to be presented with opportunities.

Therefore, in order to ensure football referees could attain an optimal level of fitness, emphasis within their fitness preparation programmes had to be firmly placed upon quality structured training sessions that provide an appropriate training stimulus to enable the attainment of such fitness. The ability to perform repeated high intensity intermittent runs along with good repeated sprint ability is a vital physiological attribute for football referees (Helson & Bultynck, 2004).

5.1 Experimental Group 1

After the pre-test, a 10 week HIIT programme, three days a week and each training session lasting an hour including stretching, warm up and cool down was administered to participants of Experimental Group 1. The participants voluntarily pledged in writing (goal-setting) to do their best during the training so that they would be able to pass the FIFA Fitness Test. An achievement of this status would definitely be a strong motivating factor for these referees and also to all aspiring referees. The participants were trained by qualified instructors. This was to ascertain that the training protocols were properly adhered to. The participants were given feed backs on their performance and were involved in brain storming discussion at the end of every training session to share or express their views.

Many studies support that goal setting and feedback are vital as they enhance performance. Therefore, in this study goal setting and feedback sessions had been used. Goal setting is becoming an increasingly popular motivational tool to use with participants to help increase performance (Weinberg & Gould, 2007). Effective feedback enhances commitment, motivation, performance strategies and most importantly performance (Neubert, 1998). Effective feedback can indicate skill level, identify performance quality and help provide information on success of the task (Kluger & DeNisi, 1996). Locke & Latham (2002) demonstrated that goal setting coupled with the use of feedback is more effective in encouraging performance than either goal setting or feedback alone. As a result of this finding, it was suggested that goals needed to be kept in constant focus. The post-test results of Experimental Group 1 indicated a significant improvement in repeated sprints after participating in a 10 Week HIIT Programme. Eighteen participants out of a total 20 passed the repeated short sprint test. Two participants failed the test as they encountered muscles cramps after the third repetition.. As for repeated high intensity intermittent runs, the post-test results indicated 16 participants in Experimental Group 1 passed the test. Four participants failed the test as they were unable to continue after completing 18 repetitions. The post-test results for Cooper 12 minute run test indicated 18 participants in Experimental Group 1 passed the test.

The results of post-test clearly indicate that a 10 Week HIIT programme improved the performance in repeated short sprints, repeated high intensity intermittent runs and aerobic power. The results also indicated that the improvement achieved was significant to pass the FIFA Fitness Test. Therefore, in this study HIIT was preferred because growing evidence suggests this type of training stimulates physiological remodelling comparable with moderate-intensity continuous training despite a substantially lower time commitment and reduced total exercise volume (Gibala & McGee, 2008). These findings are important from a public health perspective given that lack of time remains one of the most commonly cited barriers to regular exercise participation (Kimm et al., 2006; Stutts, 2002; Trost et al., 2002). Moreover, recent evidence suggests that HIIT is perceived to be more enjoyable than moderate-intensity continuous exercise (Bartlett et al., 2011).

As the objective of the FIFA Fitness Test is to test aerobic, anaerobic and speed of referees, HIIT programme was used to develop these components. HIIT was preferred because HIIT workouts are enormously popular exercise programmes in fitness industry. The training sessions typically include short bursts of intense exercise alternated with relief breaks of varying lengths (Boutcher, 2011; Kessler et al., 2012). It involves manipulation of intensity and duration of work to rest ratios where the resting periods allow the individual to rest and recover between sets (William & Costill, 1994). When a comparison on the effectiveness of HIIT and traditional endurance training methods were explored, the results indicated that HIIT tax both the aerobic and anaerobic energy releasing systems almost maximally (Tabata et al., 1996). Evidence from studies indicate that many adaptations associated with traditional high-volume endurance training can be induced faster and with a surprisingly small volume of HIIT (Burgomaster et al., 2005; Gibala et al., 2006; Hazell et al., 2010; MacPherson et al., 2011).

Further, there is evidence to suggest that inserting a relatively short period of HIIT into the already high training volumes of well-trained athletes can further enhance performance (Iaia & Bangsbo, 2010 & Laursen, 2010). Finally, match analysis studies by Spencer et al. (2005) have also demonstrated that football referees are required to repeatedly produce maximal or near maximal actions of short duration with brief recovery periods. They further stated that for these reasons, football referees training should commonly include physical activities aimed to enhance both aerobic and anaerobic power. HIIT is used widely with athletes participating in sports that require energy contribution from both aerobics and anaerobic systems (Sears, 2011). Training intensities can be effectively used in any setting in which exercise intensity can be manipulated quickly (Manna, Khanna & Dhara, 2009).

A study by Helgerud et al. (2001) showed that HIIT is an effective training strategy for improving the aerobic and anaerobic fitness, power or sprint performance of football referees. Their results have been confirmed by McMillan et al. (2005); Impellizzeri et al. (2008) who have shown that HIIT, using both specific and generic exercises is equally effective in enhancing aerobic and anaerobic fitness of football referees. Therefore, HIIT can be considered an effective training strategy for aerobic, anaerobic and sprint development in football referees. Studies by Bugomaster et al. (2005); Dawson et al. (1998); MacDougall et al. (1998) & Ortenblad, (2000) further supported that HIIT consisting of maximal or near-maximal short-term efforts (5 to 30 seconds) could produce improvements in the ability to repeat several sets of anaerobic exercise. They further reported that HIIT can also be effective in enhancing VO₂max and aerobic enzyme activity. These investigations support the effectiveness of HIIT for enhancing both the aerobic and anaerobic capacities.

Taking into consideration all the findings in the previous studies that contributed to enhancement of performance, a 10 Week HIIT programme using the components and factors that contributed to improve performance was formulated and used in this study anticipating to produce similar or better results in repeated short sprints, high intensity intermittent runs and aerobic power thereby able to pass the FIFA Fitness Test.

The rationale why a three day training programme lasting for 10 weeks was chosen is supported by the study by Gambetta (2007) indicated that significant improvement in speed, anaerobic and aerobic power in football referees occurred when they trained three days per week in 10 weeks. He reported that there was no significant difference in improvement between participants who exercised three consecutive days per week or subjects who exercised every alternate day. Rhea (2003) reported that for trained individuals a frequency of three days, one day rest between sessions is recommended. Other studies by Daussin et al. (2008); Helgerud et al. (2007); Musa et al. (2009) & Perry et al. (2008) reported that HIIT three days a week for 10 weeks produced the best results while limiting injuries to the participants

Three other studies have supported the execution of a 10 week HIIT programme performed three days a week to enhance performance. The first study by Helgerud et al. (2007) found that four repetitions of 4 minute runs at 90%–95% of heart rate, followed by three minutes of active recovery, performed three days per week for 10 weeks resulted in a 10% greater improvement in stroke volume compared to long, slow distance training three days per week for 10 weeks. He further stated that stroke volume is one of the key components of the body's ability to deliver maximum oxygen to working muscles. The second study by Daussin et al. (2007) measured the increase in VO₂max among subjects who performed 10 weeks, three days in a week of either HIIT programme or a continuous aerobic endurance exercise programme. It was found that the increase in VO_2 max was significantly higher in the HIIT programme (15%) compared to the continuous aerobic endurance group (9%). The third study by Ferrari et al. (2008) found that 10 weeks of specific repeated 20 metre short sprint training, improved 6x40m shuttle run performance. As very positive results in performance were reported in previous studies using a 10 Week, duration of three days in a week were indicated. FAM preferred to implement a 10 week HIIT programme, three days in a week.

Though a majority of studies support the use of a 10 Week HIIT programme, a few studies reported that improvement in sprints could be achieved before the completion of 10 weeks. Dawson et al. (1998) reported that six weeks of HIIT significantly improved 6 x 40 metre repeated short sprint ability performance. Whereas (Edge et al., 2005) found that five weeks of HIIT improved repeated short sprint ability test performance more than moderate-intensity continuous training. Buchheit et al. (2010) indicated that four weeks of sustained 30 metre sprint training improved repeated short sprint ability performance. Further it was found in six HITT sessions, an improvement in exercise performance has been seen ranging from 9.6% increase (Burgomaster et al., 2006) to a 100% increase (Burgomaster et al., 2005) in exercise capacity, effectively doubling the amount of time to exhaustion. HIIT protocols any longer than two weeks consistently show significant improvement in aerobic capacity. There is a minimum amount of HIIT training required to see a consistent improvement in aerobic capacity. (Burgomaster et al., 2008; MacDougall et al., 1998; MacPherson et al., 2011). All these studies supported that HIIT over 2 to 10 weeks could improve performance, particularly short sprints.

The 10 week HIIT programme was formulated taking into consideration the intensity, duration, frequency and fitness level of referees. It was expected that the 10 week HIIT programme induces the physiological systems to undergo specific adaptations that increase the body's efficiency and capacity. With the implementation of the programme it was expected that physiological responses occur in cardiovascular, respiratory, musculoskeletal, endocrine and immune systems. The magnitude of these changes probably enhanced performance in this study. Many studies supported that the physiological adaptations led to the improvement in performance. Jones & Carter (2000) indicated that HIIT causes adaptations in the pulmonary, cardiovascular and neuromuscular systems that improve the delivery of oxygen from the atmospheric air to the mitochondria and enhance the control of metabolism within muscle cells.

A number of studies showed that HIIT programmes improve cardiovascular fitness by increasing cardiac output in about three weeks and arterial-venous oxygen difference in about four to six weeks, resulting in a greater maximal endurance capacity. The physiological adaptations associated with HIIT showed enhanced aerobic performance within a period of two to fifteen weeks (Gibala et al., 2008).
During HIIT the performance of the heart is based on heart rate, the stroke volume and heart contractility or the forcefulness of each heart contraction. Combined, these variables increase blood flow and oxygen supply to meet the demands of the exercising muscles. The contraction of the skeletal muscle also increases venous blood flow return to the heart, which increases ventricle blood filling. This boosted preload contributes to the heart's enhanced stroke volume during exercise, which is a major determinant of HIIT performance (Joyner & Coyle, 2008).

Heart muscle structure adaptations are common with progressively increasing amounts of HIIT training. These adaptations include thickening of the heart muscle and increased left ventricle size, which contribute to improved heart function during exercise. Consistent bouts of HIIT training performed three days per week leads to several other cardiovascular adaptations including increased cardiac muscle mass, increased stroke volume, increased disposal of metabolic wastes, increased oxidative enzymes and efficiency, faster diffusion rates of oxygen and fuel into muscle, increased left ventricle dilation and chamber volume, increased carbohydrate sparing thus greater use for fat as fuel, increase in mitochondria, increase in cell regulatory mechanisms of metabolism, increased fat oxidation and increased expression of fatigue resistance slow twitch muscle fibres (Joyner & Coyle., 2008; Pavlik et al., 2010).

Marcus (1998) found that the capillary density of the ventricular myocardium can be increased by HIIT. The three major determinants of myocardial oxygen consumption are heart rate, myocardial contractility and wall stress He further reported that a very high correlation exists between both myocardial oxygen consumption and coronary blood flow and the product of heart rate and systolic blood pressure. During HIIT, all three major determinants of myocardial oxygen requirements increase above their resting levels. During prolonged exercise or at higher rates of work, increases in carbon dioxide production, hydrogen ions and body and blood temperatures stimulate further increases in pulmonary ventilation. At higher intensities, the respiratory rate also increases. In highly trained athletes, pulmonary ventilation rates at rest rise to more than 100 litres per minute at maximal rates of work.

It was further indicated that HIIT increases blood volume. While plasma volume accounts for the majority of the increase, a greater production of red blood cells can also be a contributory factor. Hematocrit is the concentration of haemoglobin per unit of blood. An increase in red blood cells does not increase hematocrit. This is because blood plasma increases to a greater extent than red blood cells. Hematocrit is actually reduced following training (Coyle, 1991).

HIIT enhances cardiovascular function by increasing cardiac output in four to ten weeks and the arterial-venous difference in two weeks, thus improving maximal VO_{2max} Astorino et al. (2012); Bailey et al. (2009); Talanian et al. (2007); Trilk et al. (2011). Additionally, HIIT has the additional advantage of simultaneously enhancing anaerobic performance by increasing muscle buffering capacity, glycolytic enzymes and ionic regulation (Burgomaster et al., 2005, 2006, 2007; Harmer et al., 2000; Hazell et al., 2012; Stathis et al., 1994).

Several studies have been done on football referees Driller et al. (2009); Iaia et al. (2009). The studies used HIIT training with work and rest intervals ranging from fifteen seconds to four minutes at 90 to 100% VO_{2max}, with heart rate values >90% of maximal heart rate and work to rest ratios of 1:1 - 4:1. It was shown in these studies that HIIT elicited increases in cardiovascular parameters such as heart size, blood flow

capacity and arterial distensibility Laughlin et al. (2008); Rakobowchuk et al. (2008, 2009). These changes improved the capacity of the cardiovascular system to transport oxygen, resulting in faster muscle and pulmonary VO₂ kinetics and higher VO_{2max}. This enabled a greater amount of energy to be supplied aerobically, allowing a player to sustain intense exercise for longer durations, as well as recovering more rapidly between high intensity phases of the game (Iaia et al., 2009).

Boutcher (2011) reported that acute physiological responses of a HIIT are heart rate elevates significantly, epinephrine and norepinephrine elevated 6.2 to 14.5 times greater than baseline, initially blood glucose from glycogen breakdown is elevated for exercise fuel but may decline during HIIT session, ATP and phosphocreatine decline steadily, increased levels of blood glycerol and free fatty acids suggesting an early breakdown of triglycerides, growth hormone may increase up to 10 times above baseline, venous blood return to the heart enhanced, directly increasing stroke volume, lactate levels may increase up to 10 times above baseline, sympathetic nervous system which speeds up neural signaling messages is elevated and parasympathetic nervous system which slows neural signaling messages is depressed.

The effects of HIIT on the cardiovascular system indicated clearly improvements in performance were possible due to the physiological changes that occurred due to training. Besides cardiovascular adaptations HIIT has a special effect on respiratory system. Oxygen is needed at rest and during exercise and energy supply to the active muscles increases demand of oxygen. Another important function of respiration is to eliminate carbon dioxide from the body. During exercise cellular oxidation and carbon dioxide production increase. The respiratory system maintains an efficient balance between the oxygen and carbon dioxide in the blood at rest and during exercise. There are some immediate changes that occur during HIIT programme. The immediate change that occurs during HIIT is the tidal volume increases to about 2500 mililitres. Non- athletes would not be able to increase up to this level because their capacity is less (Wesserman et al., 1994).

Gallo et al. (1995) indicated that besides an increase in tidal volume, the respiratory rate increases from 16 to 40 per minute. The pulmonary ventilation of a trained athlete may increase to around 100 litres per minute. This is because their tidal volume and respiratory rates increase. The oxygen uptake of trained athlete increases to approximately 5 litres per minute. The pulmonary ventilation of a trained athlete may increase to around 100 litres per minute the pulmonary ventilation of a trained athlete may increase to around 100 litres per minute. This is because their tidal volume and respiratory rates per minute. This is because their tidal volume and respiratory rates per minute. The pulmonary ventilation of a trained athlete may increase to around 100 litres per minute. This is because their tidal volume and respiratory rates increase during exercise

The lung diffusion capacity increases with HIIT. Trained athletes increase their diffusion capacity 30% more than that of an untrained person because trained athletes lung surface area and red blood cell count is higher than that of the non-athletes. The athletes who are under training for a long period may increase vital capacity to around six litres. An athlete's total efficiency of the lung remains at higher level than the non-athletes. This efficiency is the key factor for higher rate of oxygen uptake than non-athletes (Gallo et al.,1995).

There are some relatively permanent changes following 10 weeks of HIIT, increased vital capacity, minute ventilation, strength of respiratory muscles and oxygen diffusion are the responses of the respiratory system. The lungs increase in size and results in increases in the vital capacity. An increased vital capacity is beneficial for an athlete as more nutrients and oxygen can be supplied to the muscles. The athlete will able to work without fatigue for a longer period because of the increase in fuel source. During exercise more oxygen is inspired in a minute. More oxygen is supplied to the working muscles. As tidal volume and breathing rate increases, the minute ventilation also increases to meet the demands for oxygen. Increased minute ventilation is beneficial for an athlete because the more oxygen and nutrients that can be inspired in a minute, the better the athlete will be able to work aerobically (Gordon et al., 1995).

Gordon et al. (1995) further reported respiratory muscles include diaphragm and the inter-coastal muscles. These muscles increase in strength and as a result greater expansion of the chest cavity. More air over a longer period of time without fatigue. This is a result of HIIT and increased usage of the respiratory muscles. As the chest cavity expands more efficient inhalation and expiration occur. It indicates that more oxygen can be brought in and more carbon dioxide can be expelled from the body. This increased strength of respiratory muscles can be beneficial to an athlete because when doing aerobic activities the individual will be able to bring in more oxygen to provide the working muscles with energy. Large amount of carbon dioxide is expelled from the body.

Oxygen diffusion rate increases and as a result the oxygen and carbon dioxide will start to diffuse much quickly. When exercise is performed for a long period of time the capillaries increases in size and numbers. This has an impact on the movement of oxygen and carbon dioxide because the wider the capillaries, more oxygen is diffused from the capillaries to the tissues and more carbon dioxide is diffused from the cells to the blood. In a trained athlete transportation of oxygen and carbon dioxide is maximal. When the supply of oxygen increases the athlete would be able to work at better intensity. The better the transportation of carbon dioxide, the athlete will be less prone to fatigue (Gordon et al., 1995). Adaptations to HIIT in the muscles occur at two levels. Firstly muscle adaptations can occur at a structural level where there is a modification of actin and myosin (Birch et al., 2005). Secondly adaptations to training occur at a functional level whereby there is an increase in the maximal activities of cytoplasmic enzymes, as well as an increase in mitochondrial density, either an increase in the number of mitochondria or mitochondria size, or both. The increase in mitochondrial density triggers an increase in the aerobic enzymes Kraemer et al. (2012). For instance, Hawley & Stepto (2001) reported a 95% increase in succinate dehydrogenase, an enzyme involved in the Krebs cycle in endurance trained cyclists.

Medbo & Burges (1990) found that the increase in power after HIIT programme could be partly related to the increases in muscular performance or muscle-fibre size for muscle force production have been associated with increases in muscle fibre size. Developing muscle performance with a training programme also be partly related to increase motor unit function or neuromuscular adaptation. Their study indicated that neuromuscular adaptations such as increased inhibition of antagonist muscles and contraction of synergistic muscles account for improvements in power output.

Terjung (1995) indicated HIIT also increases the number of capillaries in trained skeletal muscle, thereby allowing a greater capacity for blood flow in the active muscle. Resistance-trained skeletal muscle exerts considerably more force because of both increased muscle size (hypertrophy) and increased muscle fibre recruitment. Kannus et al (1992) discovered that fibre hypertrophy is the result of increases in both the size and number of myofibrils in both fast-twitch and slow-twitch muscle fibres. Daussin et al. (2008) an increase in capillary density has been reported as part of the adaptations invoked by HIIT. This is an important adaptation as capillary density determines the delivery of oxygen, blood glucose and triglycerides to working muscles, as well as the rate of removal of carbon dioxide, lactate and other metabolic byproducts. The increase in capillary density was observed in three ways, which included an increase in capillary number, an increase in the number of capillaries per muscle fibre and increase in the number of capillaries per square millimetre. The increase in the number of capillaries surrounding each muscle fibre is important in that it helps maintain conditions which are conducive for aerobic metabolism by increasing the efficiency of the muscles oxidative capacity. Further, they compared the effect of eight weeks of endurance training and HIIT on muscle capillary density in sedentary women and men. They reported an increase of 3% and 2% for the endurance training and HIIT, respectively. This showed that HIIT caused similar changes in capillary density to endurance training.

Several studies indicated that ligaments and tendons become stronger with HIIT. This effect is the result of an increase in the strength of insertion sites between ligaments, tendons, bones and an increase in the cross-sectional areas of ligaments and tendons. These structures also become weaker and smaller with several weeks of immobilization which can have important implications for musculoskeletal performance and risk of injury (Tipton & Vailas, 1990).

Physiological adaptations in the central and peripheral system resulted due to HIIT. One of the first adaptations was an improvement in the aerobic enzymes, cytochrome oxidase and citrate synthase (Burgomaster et al., 2005, 2008; Gibala, et al., 2006). These adaptations are directly correlated to an increase in oxidative capacity (Gibala & McGee, 2008). Additionally, is an increase in mitochondria size and effectively increasing oxygen being transported to the muscle (Gibala, 2009). The increases are in both the fast twitch (FT) and slow twitch (ST) fibers but in different ratios as both can adapt with training.

With the increase in oxidative capacity and the physiological variables that come with HIIT, there is also an improvement in fat and carbohydrate metabolism (Gibala & McGee, 2008). HIIT increases fat oxidation, as well as conserving the glycogen stores during exercise (Perry et al., 2008; Talanian et al., 2006). The glycogen stores are conserved, even though there is an increased amount of stored glycogen at rest due to the training intervention (Burgomaster et al., 2005; Perry et al., 2008). This might suggest that the FT IIa fibers are beginning to adapt. A chronic HIIT protocol causes a decrease in lactate build-up (Bayati et al., 2011; Burgomaster et al., 2005), and an increased lactate recovery during rest (Bayati et al., 2011).

Along with the improvements in lactate and glycogen stores, were also increases in ATP and PCr production in the FT muscles (Burgomaster et al., 2008). This would suggest that the FT IIb fibers are also adapting to the stimulus. Not only does HIIT show improvement in aerobic capacity and the muscles, but there may also be physiological adaptations in the cardiovascular system. Although adaptations in the muscles and endurance performance have been consistent, it seems as though there is a minimum amount of HIIT sessions need more than two weeks to elicit adaptations in stroke volume, heart rate, cardiac output, or plasma volume (Daussin et al., 2008; Trilk et al., 2011). Boutcher (2011) completed a comprehensive research review on HIIT and reported that individuals can improve cardio-respiratory fitness (VO_{2max}) 4% to 46% in training periods lasting from 2 to 15 weeks in length. The scientific explanation for this increase in VO_{2max} from HIIT training is proposed to be a consequential increase in stroke volume which is induced by an increase in the heart muscles' contractile capability during near maximal exertion. HIIT has also been shown to increase mitochondrial biogenesis (the size and number of mitochondria, the cells ATP synthesis factory organelle) that readily translates into improved cardiovascular capacity at any level of exercise intensity. Kessler et al. (2012) add that HIIT training appears to induce rather rapid changes in VO_{2max}.

The metabolic benefit of HIIT training is the increase in post-exercise energy expenditure referred to as Excess Post-exercise Oxygen Consumption (E.P.O.C.). Following an exercise session, oxygen consumption (and thus caloric expenditure) remains elevated as the working muscle cells restore physiological and metabolic factors in the cell to pre-exercise levels. This translates into higher and longer postexercise caloric expenditure. LaForgia, Withers, & Gore (2006) noted that exercise intensity studies indicate higher E.P.O.C. values with HIIT training.

The endocrine system, like the nervous system, integrates physiologic responses and plays an important role in maintaining homeostatic conditions at rest and during exercise. This system controls the release of hormones from specialized glands throughout the body, and these hormones exert their actions on targeted organs and cells. In response to an episode of exercise, many hormones are secreted at an increased rate (Reichlin, 1992). The studies by Parolin et al. (1999) reported that during a single 30 second all out burst of maximal cycling, approximately 20% of total energy provision is derived from oxidative metabolism. However, if the exercise bout is repeated three times with four minute of recovery between bouts, ATP provision during the third bout is derived primarily from oxidative metabolism. The increased contribution from oxidative metabolism during repeated high-intensity efforts is attributable to both an increased rate of oxygen transport and utilization and a decreased ability to stimulate ATP production through the breakdown of phosphocreatine and glycogen.

HIIT is therefore unique because cellular energy during an acute bout or a given training session can be derived primarily from non-oxidative or oxidative metabolism. Kubekeli et.al. (2002). Consequently, it can elicit a broad range of physiological adaptations. Improved performance of sprints or high-intensity exercise after HIIT is related in part to increases in the maximal activities enzymes that regulate non-oxidative energy provision (Juel et al., 2006; Kubukeli et al., 2002; Ross & Leveritt, 2001).

Boutcher (2011) & Kessler et al. (2012) comprehensively reviewed studies investigating the effect of HIIT on improving insulin sensitivity and glucose metabolism. Data indicated that insulin sensitivity can be improved 23% to 58%. Study lengths vary from 2 weeks to 16 weeks for these adaptations to occur. The mechanism for this improvement appears to be well documented with the ability of the exercising muscle contractions to stimulate the glucose shuttle transporters (known as GLUT4 translocaters) to take up glucose into the working muscle from the blood not depending on whether insulin is available. All the studies indicated that physiological changes occurred in cardiovascular, respiratory, muscular, endocrine and immune system as a result of HIIT programme with a frequency of three days per week over a period of 10 weeks. These changes probably resulted in significant improvement in repeated short sprints, repeated high intensity intermittent runs and aerobic power of football referees in Malaysia.

5.2 Experimental Group 2

The pre-test was conducted on January 6, 2013 at 9.00 am at the 400 metre track, Kuala Lumpur Football Stadium (KLFS), Kuala Lumpur. The test was conducted by six qualified physical education lecturers and 20 physical education student teachers.

The pre-test results in repeated short sprints, repeated high intensity intermittent runs and aerobic power indicated that none of the participants in Experimental Group 2 passed the FIFA Test as the participants did not meet the requirements set by FIFA. In order to pass the repeated short sprint test, FIFA made it compulsory for referees to complete 40 metres x 6 repetitions within the stipulated time. To pass the repeated high intensity intermittent run test, the participants had to complete 150 metres x 20 repetitions on a 400 metre track within the stipulated time. The minimum requirement to pass the Cooper 12 minute run was 2.6 kilometres. The referees must pass all the three tests. The post-test results indicated that there was an improvement in repeated short sprints t (19) = 3.3, p<0.05. Repeated high intensity intermittent runs t (19) =8.6, p< 0.05 and aerobic power t (19) =5.6, < 0.05 but the improvement was not sufficient to pass the FIFA Fitness Test. The results indicated none of the participants passed the repeated short sprint test and repeated high intensity intermittent test and only one participant managed to complete 2.6 kilometres in Cooper 12 minute run test. All the

participants in Experimental Group 2 failed the FIFA Fitness Test. The training programme used by Experimental Group 2 solely by jogging and playing minor games was not effective to meet the requirement set by FIFA to pass the FIFA Fitness Test.

5.3 Control Group

The pre-test results and post-test results in repeated short sprints, repeated high intensity intermittent runs and aerobic power indicated that none of the participants in Control Group passed the FIFA Test as the participants did not meet the requirements set by FIFA.

5.4 Conclusion

The results of this study provide meaningful support for the conclusion that a planned HIIT programme is effective and acceptable to improve performance in repeated short sprints, repeated high intensity intermittent runs and aerobic power of the football referees. The training programme therefore, can be adopted as a formal training programme for football referees.

The results indicated that the performances of Experimental Group 1 in repeated short sprints, repeated high intensity intermittent runs and aerobic power were the best when compared with the other two groups. It also showed that the training method used Experimental Group 1 was better than the training methods used by Experimental Group 2 and Control group. Thus, from the findings of this study, it can be concluded that there are three general reasons for the improved performance in repeated short sprints, repeated high intensity intermittent runs and aerobic power of the football referees in Malaysia

Firstly, training programme of this nature provided the football referees with an opportunity to train for three days in a week under the guidance of a trained physical education instructor. The instructor, playing a direct and ever-present role was recognized and as a result served as a strong motivating factor to the participants. It was found that the exercise leaders appeared to be the single most important variable affecting training compliance and motivation.

Secondly, during the present investigation there was an intense curiosity and interest regarding the training programme; from the first exposure to instructors and at the pre-test to the last exposure at the post-test. The interest was true to Experimental Group 1.

All groups responded to the pre-test and post-test with seemingly equal engagement. Interest in the training method grew more intense for football referees in Experimental Group 1 who followed the training seriously.

Finally, the football referees in Selangor and Kuala Lumpur never had an opportunity to participate in a group training programme. This study which offered a setting to train in a group could have motivated them to train harder as they were eager to know the training effects. Several studies reported that 90% of adult exercisers preferred group programmes to those in which one trained alone. Other studies indicated poorer training compliance in individual programmes. It was further reported that social reinforcement and companionship associated with a group programme apparently facilitated increased training programme.

Within the limitations of the study and based upon the findings of this research, the following conclusions are warranted:

Firstly, a 10 week HIIT programme provides significant improvement in repeated short sprints, repeated high intensity intermittent runs and aerobic power of football referees as tested in FIFA Fitness Test.

Secondly, a 10 week HIIT programme designed for improving repeated short sprints, repeated high intensity intermittent runs and developing aerobic power is more effective than a combined training programme of jogging and minor games.

This planned HIIT programme is effective and acceptable to improve in the performance of repeated short sprints, repeated high intensity intermittent runs and to improve aerobic power of football referees. Therefore, it should be adopted as a formal training programme for football referees.

5.5 **Recommendations**

- i. More research should be conducted in the effectiveness of training programmes to improve repeated short sprints, repeated high intensity intermittent runs and to develop aerobic power.
- Future research should include participants from Malaysia football referee population and not restricted to Selangor and Kuala Lumpur only.

- iii. The study should be conducted with additional investigators, so that specific experimenter effect might be ascertained.
- iv. For future studies in Selangor or Kuala Lumpur, only participants who resided approximately within 10 kilometers from the training centres need to be selected. This is to avoid participants reporting late for training sessions due to traffic jam.

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