EFFECTS OF HIGH INTENSITY INTERVAL TRAINING AND HIGH VOLUME ENDURANCE TRAINING ON MAXIMAL AEROBIC CAPACITY, SPEED AND POWER IN CLUB LEVEL GAELIC FOOTBALL PLAYERS

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Declaration

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Abstract

Abstract

Purpose: To compare the effects of high intensity interval training (HIIT) and high volume endurance training (HVET) on indices of endurance, speed and power in male Gaelic football players.

Methods: Club level Gaelic football players (n=25) ranging from 18 to 35 years of age were randomly assigned to a HIIT (mean ± SD; 27.2 ± 3.6 yr) or a HVET (mean ± SD 24.7 ± 4.0 yr) group. Participants trained 3 $d \cdot wk^{-1}$ for 6 weeks. Maximal aerobic capacity, vertical jump (VJ), countermovement jump (CMJ), and 5 m and 20 m sprint times were measured at baseline and after 6 weeks. Participants also performed 6 x 10 sec bouts of cycling against a resistance equal to 7.5% body weight interspersed with a 50 sec recovery period before and after the 6 weeks of training.

Results: Maximal aerobic capacity increased significantly in both the HIIT and HVET group in response to the 6 week training program, and the percentage improvement was similar (7%) in both groups. There was no change in CMJ, CMJ flight time or 5 m speed in either group in response to training. Compared to baseline, performance in the VJ and 20 m sprint decreased significantly in the HVET group following the 6 week training program, and did not change in the HIIT group. Average power and peak power during the fifth and sixth cycling test increased and the rate of fatigue decreased in the HIIT group only.

Conclusion: In contrast to HVET, HIIT is a time efficient training method for improving aerobic capacity and maintaining indices of speed and power in club level Gaelic football players.

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Table of Contents **Page Number**

List of Figures

List of Tables

Definition of Terms

HIIT – High Intensity Interval Training

HVET – High Volume Endurance Training

VJ – Vertical Jump

CMJ – Countermovement Jump

$\dot{V}O_2max$ – Maximal Aerobic Capacity

GAA – Gaelic Athletic Association

AFL – Australian Football League

PC – Phosphocreatine

MyHC – Myosin Heavy Chain

FT – Fast Twitch

SDH - Succinate Dehydrogenase

NFL - American Football league

CSA - Cross Sectional Area

AT - Anaerobic Threshold

HVT - High Volume Training

MAS - Maximal Aerobic Speed

ET - Endurance Training

LT – Lactate Threshold

M – Metre

Sec - Second

CHAPTER 1

INTRODUCTION

Gaelic football is one of the most popular sports in Ireland. It can be described as a hybrid of soccer, rugby and basketball, although it predates all of these games [1]. It is a field based sport played by two teams of 15 players. Each team has a goalkeeper, six defenders, two midfield players and six forwards. The ball is slightly larger and heavier than that used in soccer, and may be caught, and/or kicked from the ground or hands. A point is awarded when the ball is kicked or hand passed over the crossbar and a goal, which is worth 3 points, is awarded when the ball passes between the post underneath the bar [2]. Adult club level and inter-county games are 60 min and 70 min in duration, respectively.

Gaelic football is characterised by irregular changes of pace and anaerobic efforts interspersed with periods of light to moderate aerobic activity [3]. Club level players cover approximately 7.0 km during a game [4], the majority of which is spent jogging (24%) and walking (48%) [5]. The aerobic energy system contributes significantly to these low to moderate intensity level activities. Many of the important events during the course of a game involve single or repeated bouts of activity involving high running velocities and muscle power. The duration of these high intensity activities is largely unpredictable, due to the fact that they are imposed by the pattern of play and can vary greatly from player to player and from one game to another. Primarily, they rely on the phosphagen system and anaerobic glycolysis and the relative contribution of each system is dependent, in large part, on the intensity and duration of the high intensity activity and the recovery intervals.

Although the phosphagen system can produce 3.6 moles of ATP per min or 1.6 kcal/sec, its maximal capacity is only 0.7 moles of ATP (11 kcal) due to small muscle stores of PCr (90-160 mmol/kg/dw). The phosphagen stores are replenished during recovery in coupled reactions from the energy released from ATP. The ATP is provided primarily by the aerobic system through the O_2 consumed during the fast component of the recovery O_2 period. Therefore, a high aerobic capacity ($\dot{V}O_2max$) enhances recovery from short duration high intensity activities. In addition, a high $\dot{V}O_2max$ will also decrease reliance on anaerobic glycolysis. Studies involving soccer players have found that a high $\dot{V}O_2max$ is associated with a higher playing intensity, increased number of repeated sprints, increased involvement with the ball and greater distance covered in a game [6].

The primary purpose of any training program is to optimize performance during competition. To accomplish this goal, the coach/trainer needs to design and implement a comprehensive conditioning program that allows players to cope with the physical demands of the game while taking account of the large inter-individual variation in physiological response to training. Cellular, organ and systemic alterations occur in a relatively predictable and uniform manner when conditioning programs are appropriately designed and implemented.

High volume endurance training (HVET), a form of training that involves continuous running undertaken at low to moderate intensities has been traditionally used to improve aerobic capacity in club level Gaelic football players. A large number of laboratory-based studies have found that one to six months of HVET results in significant improvements in $\dot{V}O_2max$ and endurance performance [7–9]. While ideal for developing aerobic capacity, HVET

is time consuming, may lack the specificity required to develop or maintain running speed and muscle power and may even be detrimental to their development and maintenance. Surprisingly, no published studies have examined the effect of HVET on indices of speed and power in athletes participating in field based invasion sports.

High intensity interval training (HIIT) involves repeated short duration (10 s – 300 s) bouts of high intensity exercise interspersed with periods of active or passive recovery. Compared to HVET, this type of training is less time consuming, allows players to undertake a greater volume of high intensity activities and improves $\dot{V}O_2$max. Burgomaster et al., (2008) [10] found that 6 weeks of HIIT on a cycle ergometer elicited similar improvements in $\dot{V}O_2$max despite a much lower training volume and time commitment. By design, weekly training volume was 90% lower in the HIIT group and necessitated a training time commitment that was only one-third of that of the HVET group (9 h vs. 27 h). Most of the training time in the HIIT group was spent in recovery between short, intense bursts of all out cycling and actual weekly exercise time was approximately 10 min, as compared to 4.5 h of continuous moderate-intensity cycling in the HVET group.

A number of other recent studies have also found that brief repeated sessions of HIIT, elicits physiological and metabolic adaptations that resemble traditional HVET. Given the markedly lower training volume involved with HIIT, this form of training may be used as a potential time-efficient strategy to increase $\dot{V}O_2$max and endurance performance and induce specific metabolic adaptations during exercise that are comparable to traditional HVET.

Motor units are recruited according to the size principle [11]. The smallest motor units are recruited initially and as the force, speed and power required increases, larger motor units are recruited [11]. It is impractical to assess motor unit recruitment during HIIT. However, the fact that a number of studies have found that HIIT improves an athlete's ability to maintain running speed [12–14] and muscle power[15–19] would suggest that this form of training recruits and trains fast twitch motor units.

To date, no studies have compared the effects of HIIT and HVET involving running on $\dot{V}O_2$max, running speed and muscle power in club level Gaelic football players. The purpose of this study is to compare the effects of 6 week HVET and HIIT programs on $\dot{V}O_2$max, running speed and muscle power in club level Gaelic football players.

1.1 Study Aims

1. To compare the effects of a 6 week HVET and HIIT programs on $\dot{V}O_2$max in club level Gaelic football players
2. To compare the effects of a 6 week HVET and HIIT programs on 5 m and 20 m running speed in club level Gaelic football players
3. To compare the effects of a 6 week HVET and HIIT programs on countermovement jump (CMJ) and vertical jump (VJ) performance in club level Gaelic football players
4. To compare the effects of a 6 week HIIT and HVET programs on peak power output, mean power output and fatigue index in club level Gaelic football players

1.2 Study Hypotheses

1. There will be a similar increase in $\dot{V}O_2$max in response to a 6 week HVET and a 6 week HIIT program in club level Gaelic football players
2. 5 m and 20 m running speeds will increase significantly in club level Gaelic football players following 6 weeks of HVET and will not change following 6 weeks of HIIT
3. Performance in the CMJ and VJ will decrease significantly in club level Gaelic football players following 6 weeks of HVET and will not change following 6 weeks of HIIT
4. Peak power output, mean power output and fatigue index will decrease significantly in club level Gaelic football players following 6 weeks of HVET and will not change following 6 weeks of HIIT

CHAPTER II
LITERATURE REVIEW

Introduction

The Gaelic Athletic Association (GAA) was established in 1884 with the aim of promoting the traditional Irish games of hurling, camogie, handball, Gaelic football, rounder's and athletics. It is the largest sporting organisation in Ireland and, with the exception of a relatively small number of administrative staff and games development officers, is entirely dependent on voluntary input. Parish or community based clubs form the basic unit of the GAA and competitions are organized from underage to senior level. Like any sporting organization, there is a hierarchical competitive structure. Top level players are selected to represent their county team.

Gaelic football can best be described as a hybrid of soccer, rugby, basketball and Australian Rules football, although it predates all of these games. It is a fast, physical contact game played between two teams of 15 players on a rectangular grass surface 145 m long and 90 m wide. The exact positioning of each player may vary depending on the tactics employed. The ball, which is similar in size but slightly heavier than that used in soccer, can be played over any distance by foot or hand, and can be carried using the accepted solo running technique [20]. This involves kicking the ball from foot to hand while moving. Goalposts with a crossbar are located on both end lines. The primary objective of the team in possession is to create and exploit space in order to score. A team is awarded a point when the ball is kicked or hand-passed between the posts and over the crossbar. A goal is awarded when the ball crosses the end line between the goal posts and under the crossbar.

Three points are awarded for a goal. When the opposition has possession, the primary aim is to decrease the time and space available in order to prevent them from scoring and to regain possession of the ball.

Similar to soccer and Australian Rules football, Gaelic football involves repeated, short duration, high intensity bouts of anaerobic exercise interspersed with sustained light to moderate aerobic activity [20]. Speed and power are essential fitness components for optimal performance [21]. At the highest level, adult players perform 96 bursts of high intensity activity lasting 6 sec followed by an average recovery of 37 sec [22]. Low intensity aerobic activity (e.g. walking, jogging) constitutes 86% of total playing time, and a high level of aerobic conditioning is required to generate and maintain power output during repeated high intensity efforts [23,24]. Players typically work at 80% of maximum heart rate during competitive games [4].

Recent advances in sports science have allowed coaches and trainers to become more scientific in the preparation of teams. However, despite its popularity, Gaelic football has lagged behind similar field sports such as soccer, rugby and Australian Rules football in terms of performance related research. There is currently relatively little evidence based research to assist coaches in designing and implementing conditioning programs, particularly in relation to the development of aerobic endurance, speed and power.

Traditionally, high volume endurance training (HVET), involving steady state running, has been used and still is the preferred method of training at club level. Although ideal for the development of aerobic endurance, this type of training is time consuming, and may

lack the specificity required to develop or maintain speed and power. A number of recent studies have shown comparable changes in molecular and cellular adaptations in skeletal muscle and endurance exercise performance in response to short duration HIIT and HVET [10,25]. In addition to improving endurance exercise performance, HIIT may also maintain speed and power in Gaelic football players.

This chapter reviews aerobic endurance, speed and power including their measurement and compares each of these fitness indices in Gaelic football to other team sports. HIIT and HVET training programs are compared in relation to their effects on speed, power and endurance with special emphasis on the training principles of overload and specificity as they relate to program design.

2.1 Running Speed

Speed can be defined as movement distance per unit time and is typically quantified as the time taken to cover a fixed distance [26]. Maximum sprinting velocity over distances ranging from 5 to 40 m has been identified as a characteristic of elite players in Australian Rules football, American football, and junior rugby league [21,27–29]. Performance in a 40 yard sprint is one of the primary physiological characteristics that discriminate between drafted and non-drafted players across all positional categories in American football [28]. Similarly, drafted Australian Rules players have significantly better 5 m, 10 m and 20 m sprint times than non-drafted players [27]. In addition, starters in an elite Australian Rules Football (AFL) team performed significantly better than non-starters in both standing 10 m and flying 30 m

sprint times [30]. McIntyre M., (2005) [31] found no significant difference in 15 m sprint performance between Gaelic football players, hurlers and soccer players.

The considerable variation in positional demands in team sports requires different fitness attributes. Positional differences in running speed have been found in a number of team sports including soccer and rugby league [21,32–34]. Sporis *et al*., (2009) [34] compared positional differences in 5 m, 10 m and 20 m running speed among elite soccer players. Goalkeepers had significantly slower 10 m and 20 m sprint times than other team members. Forward players were significantly faster over 5 m, 10 m, and 20 m than midfield players. However, goalkeepers compared favourably with other positions in the 5 m sprint times and there was no difference in sprint times over 5 m, 10 m, and 20 m between forward players and defenders [34]. Considering that the wing players in professional rugby league rely heavily on speed during the course of game, it is not surprising that they have faster 15 m sprint times than forward players and, with the exception of hookers, have a faster 40 m sprint time than forward positions [33]. Amateur rugby league backs are faster over 40 m than forwards [32] and elite level junior level rugby league outside backs are significantly faster over 10 m, 20 m, and 40 m than players in any other position [21].

2.2 Acceleration

Maximal sprinting speed, although important, is only one aspect of the speed requirements for Gaelic games. Acceleration is the rate of change of velocity as a function of time [26]. It is calculated by subtracting the initial speed from the final speed and dividing by the time. A player who moves from a stationary position to 5.21 m/sec in 0.96 sec will

have an acceleration of 5.42 m per sec every sec, i.e., the speed is increasing by 5.42 m per sec every sec. The time required to complete 10 m has been identified as the most significant predictor of 40 m sprint time, highlighting the importance of rapid acceleration to overall sprint performance [35]. Brechue *et al*., (2010) [36] found that maximal acceleration is attained at 9.1 m and maintained through 18.3 m during a 36.6 m sprint in a study of collegiate level American football players. Sprint performance was largely determined by acceleration, a pattern that was consistent across positions.

2.3 Power

Power is a measure of work performed per unit time [37,38]. It is expressed as (F x D)/T), where F is the force generated, D is the distance through which that force is moved and T is the duration of the exercise. Many of the important activities in Gaelic football such as competing for possession, breaking a tackle, jumping to catch a kick-out and accelerating from a stationary position require muscular power.

A number of laboratory and field based tests have been developed to measure muscle power. The Margaria-Kalamen test measures maximal power output during stair climbing. Power output (P) is calculated using the formula; $P = (W \times 9.8 \times D)/t$, where W is the body mass of the subject in kilograms; 9.8 is the normal acceleration due to gravity in ms−2; D is the vertical height in metres between selected steps; and t is the time taken to complete the test.

The Wingate anaerobic test involves cycling at maximal effort against a resistance equal to a percentage of body mass for a fixed duration. The test measures peak power

(watts), average power (watts) and fatigue rate (%) [39]. The most popular protocol for the Wingate test involves cycling against a resistance of 7.5% body mass for 30 sec. However, protocols involving multiple 10 sec bouts interspersed with short recovery periods may be more appropriate for assessing muscle power in Gaelic football players. A major weakness of the Wingate test is that it may lack the specificity required to assess peak power in non-cyclists. The need for specialised equipment and trained personnel has impeded the widespread use of the Wingate and Margaria - Kalamen tests in intermittent team sports [39].

2.3.1 Power Assessment - Field Based Tests

A number of explosive jump tests have been developed to assess lower limb muscular power in athletes. Each of the jump tests is performed from a stationary position and involves coordination of the upper and lower-body segments [40]. The stretch shortening cycle, trunk extension and head movements are initiated prior to each jump to develop maximum elastic and contractile energy in the muscles [41]. Upper body and abdominal strength are used to create good posture and act to conduct forces between the upper and lower body [42]. The counter-movement jump (CMJ) measures vertical displacement with both hands placed on the hips throughout the duration of the jump (Figure 2.1).

Figure 2.1: Countermovement jump (CMJ)

A counter-movement jump with arm swing, commonly described in the literature as a vertical jump (VJ), permits a co-ordinated arm swing back to aid vertical displacement (Figure 2.2) Studies in men and women found that the height attained in the VJ test was higher than the CMJ test [40,43]. Elevation of the arms in the VJ raises the centre of mass, and may contribute to the superior jump height achieved in the VJ than the CMJ. Furthermore, increased velocity at take-off may be elevated due to a series of events in which the arms build-up energy early in the jump which is then transferred to the rest of the body [40].

Figure 2.2: Vertical jump (VJ)

The intraclass correlation co-efficient for college age men performing 3 CMJ tests with 1 min recovery between trials was 0.98 [44]. When averaged across three CMJ tests, undertaken during four testing sessions separated by one week the correlation coefficient for the CMJ test re-test reliability among college age men and women ranged from 0.87-0.96 [45]. Slinde *et al*., (2008) [43] examined the test re-test reliability of the vertical jump test with and without arm swing. Men and women between the ages of 18 and 25 years completed three non-consecutive VJ and CMJ tests on two occasions separated by 7 days. The highest score in each test was selected. High and statistically significant intraclass correlation coefficients were found for the VJ (r = 0.93) and the CMJ (r = 0.93) tests.

Jump tests may be a suitable alternative to the Wingate and Margaria–Kalamen tests. Vertical jump performance is significantly related to peak power and mean power output during a 30 sec Wingate test [39]. Using a standard linear regression model, Davis *et al*., (2003) [46] found a strong relation between performance in the Margaria-Kalamen test and vertical jump performance.

2.3.2 Power – Gaelic football players

VJ height ranges from 50 - 65 cm in Gaelic football players (Table 2.1). Among elite collegiate level Gaelic football players, midfielders produce greater power during the VJ as well as greater vertical displacement than all other positions [2]. This is perhaps not surprising considering that midfield players are required to compete for aerial possession more frequently than players in any of the other positions. Performance in the VJ test is similar in collegiate level defenders and forwards and elite inter-county players [2,47].

Table 2.1: Studies that evaluated Vertical jump performance in Gaelic football players

	Level	Position	n	VJ (cm)
(McIntyre & Hall,2005) [2]	Collegiate	Defender	12	54.0 ± 7.2
-	Collegiate	Forward	12	56.0 ± 6.0
-	Collegiate	Midfield	4	65.0 ± 4.0
(Watson, 1995) [47]	Inter-county	-	32	50.3 ± 5.8
(Keane *et al*, 1997)[48]	Club	-	36	58.4 ± 6.4
(Kirgan & Reilly, 1993) [49]	Club	-	15	48.6 ± 4.7

Values are mean ± SD

Performance in the VJ differentiates between elite and sub-elite rugby league players [21] while no positional differences were found in VJ test performance among junior and amateur rugby league players [32,50]. Performance in the VJ is similar among drafted and non-drafted AFL players [27] and among starters and non-starters of professional [30] and elite

level junior players [51]. However, among professional AFL players, starters perform better than non-starters in the CMJ test [30] and CMJ and VJ discriminated between starters and non-starters in elite junior level players [52,53]. Interestingly, elite soccer goalkeepers have been shown to perform better in explosive power tests including the CMJ test than all other positions [34].

Table 2.2: Vertical jump scores in different sports

Study	Spot/ Standard	N	Age	Jump Score
(Wong 2004) [54]	Soccer (Youth Elite)	16	16.2 ± 0.6	39.33 ± 4.82
(Chamari 2004) [55]	Soccer (Youth Elite)	34	17.5 ± 1.1	51.3 ± 6.7
(Wisloff 2004) [56]	Soccer (Pro)	17	25.8 ± 2.9	56.4 ± 4.0
(T. J. Gabbett 2002) [57]	Rugby league (First Grade Forwards)	11	25.1	48.7
	Rugby league (First Grade Backs)	9	23.4	50.9
	Rugby league (U-19 Forwards)	10	17.8	37.9
	Rugby league (U -19 Backs)	12	17.3	40
	Rugby league (U -16 Forwards)	12	15.4	38
	Rugby league (U -16 Backs)	9	15.6	41.2
(Gissis 2004) [58]	Soccer (elite)	18	16.3 ± 1.26	23.6 ± 3.5
	Soccer(Sub Elite)	18	16.4 ± 1.32	21.4 ± 4.5
	Soccer(Recreational)	18	16.2 ± 1.29	20.3 ± 4.3
(Ostojic 2004) [59]	Soccer (Elite)	30	24.1 ± 2.5	49.9 ± 7.5
	Soccer (Nonelite)	30	21.8 ± 2.8	43.9 ± 6.9
(Kasabalis & Douda 2005) [60]	Athlete(Volleyball)	21	10 -11	25.44
	Athlete(Volleyball)	18	15 -16	44.41
	Athlete(Volleyball)	17	18 -25	46.68
	Non Athlete	18	10 -11	19.04
	Non Athlete	20	15 -16	32.95
	Non athlete	15	18 -25	35.66

Values are mean ± SD

Evidence from a study of a successful Gaelic football team shows that VJ scores were similar to other codes but were lower than that reported for Australian rules, while the jumping ability of the midfielders was similar to that found in Australian rules players [47]. Vertical jump performance scores are 3.4% higher in American football players than basketball players [61]. Elite soccer players have been found to perform better in the vertical jump test than sub elite and recreational players [58 59].

2.4 Aerobic Fitness

Gaelic football is characterised by irregular changes of pace and anaerobic efforts interspersed with periods of light to moderate aerobic activity [20]. Intercounty level Gaelic football players cover an average distance of 8.5 km during a game at an average intensity of 71% $\dot{V}O_2max$ [5,20]. In contrast, club level players cover approximately 7.0 km during a game [4]. The majority of time, at both intercounty and club level, is spent jogging and walking (Figure 2.3) [5]. Less than 1.7% of total playing time involves sprinting [5]. Consequently, the aerobic energy system contributes significantly to the total energy released during the course of a game.

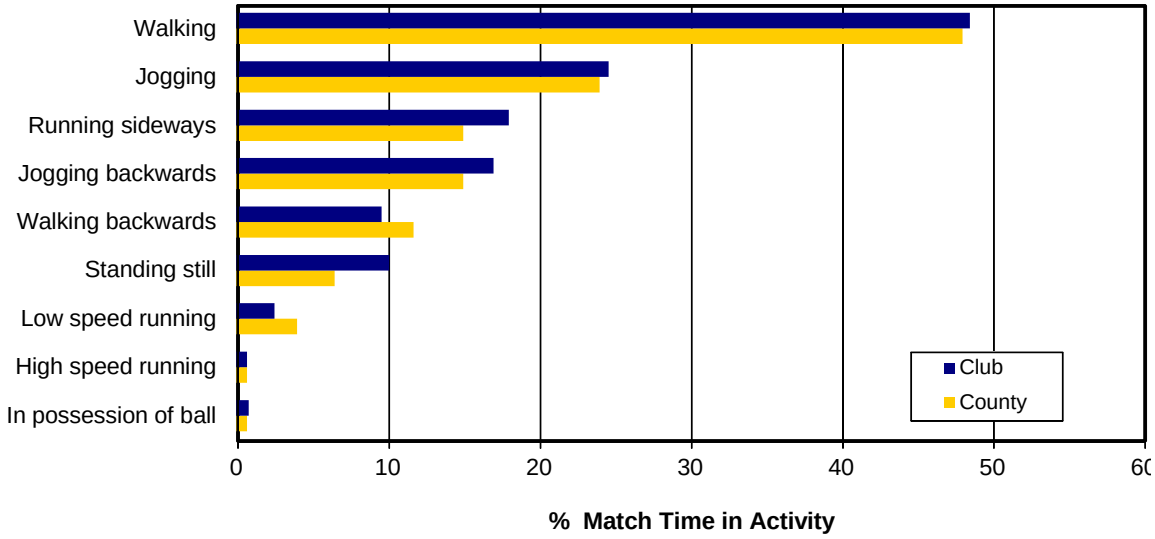

Figure 2.3: % Match time activities[5]

The high intensity activity bouts undertaken during Gaelic football are largely unpredictable and are imposed by the pattern of play and vary greatly from player to player and from one game to another. Muscle phosphocreatine stores and the breakdown of carbohydrates during anaerobic glycolysis provide the most rapidly available source of energy for rephosphorylating ADP during short duration high intensity exercise [62]. Their relative contribution is dependent, in large part, on the intensity and duration of the high intensity activity and the recovery intervals [63].

Phosphocreatine stores that are depleted during high intensity exercise bouts are rapidly replenished from the hydrolysis of ATP during recovery from exercise. Under normoxic conditions, the ATP required for phosphagen restoration is provided primarily by the aerobic system through the oxygen consumed during the fast component of the recovery oxygen period [62]. The greater the phosphagen depletion during exercise, the greater the oxygen required for restoration during recovery.

Maximal aerobic capacity is an integrative measure of the ability of the lungs to supply oxygen, the cardiovascular system to pump and transport oxygenated blood to the

exercising muscle, and the ability of the working muscles to utilize oxygen [62], [64]. According to the Fick Principle, oxygen uptake is the product of cardiac output and arteriovenous oxygen across the body. This implies that both central (oxygen delivery) and peripheral (oxygen extraction) factors are important in ensuring that the muscle receives an adequate supply of oxygen during exercise [65].

The majority of studies that have examined the relation between $\dot{V}O_2$max and performance during invasive team sports have involved soccer and the findings have been equivocal. Elite junior level Norwegian players with the highest $\dot{V}O_2$max, had a greater number of touches of the ball during a game, made a greater number of sprints and covered a larger distance than players with a lower $\dot{V}O_2$max [6] . In contrast, Roi *et al.,* (1993) [66] , found no relation between $\dot{V}O_2$max and the final position in the Italian soccer league. Aziz *et al*., (2007) [67], examined the relation between aerobic fitness levels and positional ranking among professional soccer teams in Singapore from 2002 – 2004, and found a significant relation between aerobic fitness and positional ranking during the 2003 season, but not during the 2002 or 2004 season.

It is not uncommon for Gaelic football players to undertake repeated bouts of short duration high intensity activity with recovery periods which don't allow for complete restoration of phosphagen stores. Under these conditions, there will be an increased reliance on anaerobic glycolysis. The breakdown of carbohydrates during anaerobic glycolysis results in increased cellular levels of pyruvate and the reduced form of the co-enzyme, nicotinamide adenine dinucleotide in the cell. In order to maintain the redox potential of the cell, the hydrogen atoms are shifted from NADH to pyruvate in the lactate

dehydrogenase reaction, and lactic acid is formed. Lactic acid diffuses into the extracellular space and accumulates in the blood. Because of its low pH, lactic acid dissociates resulting in an increase in H^+ levels and a decrease in intracellular pH. This in turn will have a deleterious effect on muscle function. An increase in $\dot{V}O_2$max could potentially decrease the reliance on anaerobic glycolysis resulting in lower circulating levels of lactic acid [62].

A high $\dot{V}O_2$max may also be related to an increased aerobic contribution to repeated sprints and enhanced ability to resist fatigue during intermittent activity [68,69] **.** Professional basketball players have a higher $\dot{V}O_2$max than amateur players and are able to repeatedly produce short, maximal bouts of exercise more often than amateur players [68]. Tomlin and Wenger.,(2002) [69], examined the relation between $\dot{V}O_2$max, power maintenance and oxygen consumption during intense intermittent exercise among moderate and low fit female recreational soccer players. The women performed 10 x 6 sec sprints on a cycle ergometer interspersed with 30 secs active recovery. Oxygen uptake was measured during exercise and recovery. Peak power output was similar in both groups. The decrement in power over the 10 sprints was smaller in the moderate fitness group than the low fitness group. Oxygen consumption was significantly higher during 9 of the 10 sprints in the moderate fitness group than the low fitness group. There was a significant positive relation between $\dot{V}O_2$max and oxygen consumption (r = 0.78) and a significant inverse relation (r = - 0.65) between $\dot{V}O_2$max and the percentage decrement in power output over the 10 sprints. Meckel *et al*., (2009) [70], also found a moderate inverse relation (r = - 0.60) between the performance decrement in a 12 x 20 m repeated sprint test and $\dot{V}O_2$max in elite adolescent

soccer players, indicating that the aerobic system may contribute to maintaining the intensity level of short bursts of activity .

In contrast, Wadley & Rossignol., (1998) [71], found no evidence of a relation between aerobic capacity and performance in a repeated sprint assessment consisting of 12 x 20 m sprints in youth Australian Rules football players. A recent review of aerobic conditioning in field sports highlighted that $\dot{V}O_2max$ is moderately related (r = 0.62 - 0.68) to repeat sprint ability in field hockey, rugby union and soccer [23].

2.5 Training

The physiological adaptations and the magnitude of improvements in exercise performance in response to training vary depending on genetic factors, age, initial fitness level, the intensity, type and duration of the contractile activity, nutritional status and other lifestyle habits such as sleeping patterns, alcohol consumption and tobacco use [26,62,65,72]. Most training programs manipulate the intensity, type and duration of the contractile activity to induce training effects.

A training stimulus that disturbs the equilibrium of the internal environment and temporarily lowers the power generating capacity of muscle is called overload. Appropriately planned, systematic increases in the training load coupled with optimal recovery will induce adaptive changes in the structure and function of cells, tissues and organs systems that are disturbed during the workout. The physiological adaptations, called training effects increase fitness levels and help to diminish the magnitude of the disruptions to the internal environment from future exercise at the same absolute intensity. In

subsequent sessions, this permits an athlete to exercise for a longer duration at the same absolute work rate before the onset of fatigue.

According to the principle of specificity, the physiological adaptations to exercise training are highly specific to the motor units recruited and their recruitment pattern. Individual muscle fibres are supplied by a single alpha (α) motor nerve. A single alpha (α) motor neuron and all the muscle fibres it supplies is called a motor unit and is the basic functional unit of the body's motor control system. The number of fibres in a given motor unit varies depending on muscle size and function. When a motor neuron is stimulated, all the muscle fibres in that motor unit contract to their fullest extent or not at all (all or none principle).

Muscles fibre types differ phenotypically in that they express different subsets of myosin heavy chain genes that influence their contractile properties (maximal velocities of shortening) and metabolic properties (major metabolic pathway used to synthesise ATP). Time to peak tension is a contractile property that is frequently used to characterize muscle fibres. At least three type II fibre types with distinct contraction speeds have been identified; fast oxidative IIA, fast intermediate IIX and fast glycolytic IIB. Each of these fibres expresses IIA, IIX and IIb myosin heavy chain (MyHC) genes and the corresponding MyHC proteins hydrolyse ATP successively faster so that the fibre types contract with progressively faster kinetics [73]. Indeed, the MyHC composition of muscle fibres is a major determinant of the contractile characteristics, influencing maximal shortening velocity and maximal power output. Slow twitch (ST) or type I fibres are innervated by α1 motor neurons and reach peak

tension in approximately 100 ms. In contrast, fast twitch (FT) or type IIb fibres are innervated by larger α2 motor neurons and reach peak tension in approximately 50 ms.

Fibre recruitment pattern is determined by the force or power output necessary to perform the movement [62]. Small α1 motor neurons have low excitation thresholds and are recruited at low workloads. In contrast, larger α2 motor neurons have higher excitation thresholds and are sequentially recruited for progressively more forceful movements. Speed and/or power development will therefore depend greatly on the individual's ability to recruit fast twitch motor units.

Muscle fibres display considerable plasticity when exposed to different functional demands. This intrinsic ability to phenotypically to adapt to different functional demands extends to all aspects of their biochemical and morphological properties. The upper limit of an individual's genetic potential dictates the absolute magnitude of the training adaptation [62]. Speed and endurance-training programs yield differences with regard to the degree of MHC-based fast-to-slow fibre type transitions and changes in fibre CSA. These differences may provide the basis for developing specific programs to develop speed and endurance. For example, endurance training appears to induce fibre type remodelling resulting in a lower proportion of histochemically identified type IIb fibres, a concomitant increase in the proportion of hybrid fibres expressing MHCIIa and little or no change in cross sectional area (CSA) of all fibre types [74]. In contrast, HIIT may not induce the same degree of fast-to-slow fibre type transitions, but results in an increase in CSA.

2.6 Endurance Training

At various times during the course of a game, players may be required to perform repeated bouts of short duration high intensity sprints interspersed with short recovery intervals. Depending on the aerobic capacity, these exercise bouts will increase the reliance on anaerobic glycolysis. The resultant dissociation of H^+ from lactic acid will decrease in intracellular pH, which in turn may have a deleterious effect on muscle function resulting in fatigue. A number of studies have found a significant relation between $\dot{V}O_2$max and repeat sprint ability in team sports such as hockey, soccer and rugby [75]. McMahon *et al*., (1998) [76] also found a significant relation between aerobic capacity and recovery from short-duration high intensity bouts and the ability to maintain power/performance in future bouts.

In addition to its role in oxidative phosphorylation, the aerobic system also plays an important role in phosphagen repletion. High intensity activities are fuelled by the phosphagen stores and the breakdown of carbohydrates during anaerobic glycolysis [62]. The relative contribution of each energy system is dependent in large part on the intensity and duration of the high intensity activity and the recovery intervals [62]. Phosphagen stores are re-synthesised in coupled reactions from the energy released during ATP hydrolysis. The ATP required is provided primarily by the aerobic system through the oxygen consumed during the fast component of the recovery oxygen period. The greater the phosphagen depletion during exercise the greater the oxygen required for restoration during recovery [77].

Regularly performed endurance training induces a variety of metabolic and morphological responses/adaptations in skeletal muscle that function to minimize cellular

disturbances during subsequent training sessions and improve endurance performance [78]. These morphological changes, along with increased capillary supply, result in a shift in trained muscle to give a greater reliance on fat as a fuel with a concomitant reduction in glycolytic flux and a tighter control of acid base status. Taken collectively, these adaptations result in an enhanced endurance performance capacity. Endurance training is also associated with an increase in the activities of key enzymes of the mitochondrial electron transport chain and an increase in mitochondrial protein concentration.

A large number of studies have evaluated the physiological and biochemical responses to endurance exercise training. In one of the earliest studies, Gollnick *et al*., (1973) [8], found a significant increase in $\dot{V}O_2$max (13%), succinate dehydrogenase activity and phosphofructokinase activity in 6 recreationally active individuals in response to 60 min of cycling at 75-90% $\dot{V}O_2$max, 4 d/week for 5 months. Similarly, 8 weeks of cycling at 80% $\dot{V}O_2$max (40 min per day, 4 times per week), increased $\dot{V}O_2$max by 16% (range; 10-27%) in healthy men [7]. The percentage of type I and type IIC fibres was unchanged with training. In contrast, the percentage of type IIA fibres increased and was accompanied by a corresponding fall in the percentage of type IIB fibres. Mean muscle fibre area was 4150 μm^2 before and 50201 μm^2 after training. The increase was due to an increase in the area of all three fibre types.

Maximal aerobic capacity increased 9% in sedentary young (26 ± 2) men and women in response to exercise training at 60-70% $\dot{V}O_2$peak, 2 h per day for 7-10 days [79]. There was also a significant increase in citrate synthase, thiolase, B-hydroxyacl-CoA and

carnitine acetyltransferase activity. Compared to pre-training, blood lactate concentration was significantly lower at the same absolute work rate after training. Davis *et al*., (1979) [9] found a 25% increase in $\dot{V}O_2$max in previously sedentary men (43 ± 2.4 yr) following 9 weeks of endurance cycling (45 min/day, 5 d/week).

2.7 Interval Training

Interval training consists of repeated bouts of moderate to high-intensity exercise interspersed with periods of rest or reduced intensity exercise [65]. The German coach Woldeman Gerschler has been credited with formalizing interval training in the 1930's. Interval training is based on the concept that a greater amount of work can be performed at higher exercise intensities with the same or less fatigue compared to continuous training [26]. Interval training can be manipulated by altering the i) distance of the run, ii) recovery duration, iii) number of repetitions, iv) time of the run and v) actions undertaken during recovery. High-energy phosphagens, anaerobic glycolysis and oxidative metabolism all contribute to ATP turnover to supply energy during short-term bouts of brief maximal intensity exercise. Athletes can perform a considerably greater volume of exercise by breaking the total exercise period into shorter more intense bouts with rest or active recovery intervals inserted between the intense bouts [65].

High intensity interval training (HIIT) may be a potent, practical, and time-efficient exercise strategy for improving fitness in Gaelic football. There is an extensive body of literature examining the effect of high intensity interval training on endurance exercise

performance [6,10,18,25,80,81]. Relatively few studies have examined the effect of HIIT on indices of speed and power.

Using competitive male and female triathletes Zuniga *et al*., (2005) [82] compared the physiological, metabolic and perceptual responses during 4 different interval training (IT) sessions. Participants exercised on a cycle ergometer at 90% maximum power output (MPO) for 30 sec and 3 min and at 100% MPO for 30 sec and 3 min with a 1 to 1 exercise-recovery ratio. The active recovery was performed at 50% MPO. Each interval training session was 30 min in duration or lasted until the participant was unable to maintain the required power output. The total time at high intensity exercise and total VO_2 during a single exercise session was greater during short durations (i.e., 30 secs) and sub-maximal intensities (i.e., 90% MPO). Participants were able to complete a longer interval training session with greater metabolic demands (VO_2) and lower circulating levels of blood lactate during short duration than longer (i.e., 3 minutes) intervals.

In recreationally active men, 6-weeks of high intensity interval training, involving 6 x 90 s bouts of cycling at 80% $\dot{V}O_2$max interspersed with 180 s passive rest period, 3 times per week resulted in a significant increase in $\dot{V}O_2$max, mean power, peak power and max power during a Wingate test [83]. MacDougall *et al*., (1998) [18] examined the effects of 7 weeks of sprint interval training on muscle glycolytic and oxidative enzyme activity in 12 healthy young men. Participants were physically active fitness enthusiasts who engaged in jogging, weight training and intramural sports. Training consisted of 30 s of maximum sprint efforts (Wingate protocol) interspersed with 2-4 min of recovery performed three times per week.

The program began with four intervals with 4 min of recovery per session in week 1 and progressed to 10 intervals with 2.5 min of recovery per session by week 7. The training program resulted in significant increases in peak power output, total work over 30 sec, and $\dot{V}O_2$max. Maximal enzyme activity of hexokinase, phosphofructokinase, citrate synthase, succinate dehydrogenase and malate dehydrogenase were also significantly higher after training.

Parra *et al*., (2000) [84] examined the effect of the distribution of rest periods on the efficacy of interval sprint training. Active college age men were randomly assigned into two groups and performed distinct incremental sprint training protocols, in which the muscle load was the same (14 sessions), but the distribution of rest periods was varied. The short program group (SP) trained every day for 2 weeks, while the long program group (LP) trained over a 6 week period with a 2 day rest period following each training session. Participants performed a 30 s Wingate cycling test on a cycle ergometer, and had a biopsy taken before and after training.

The first three training sessions involved two bouts of 15 s sprints and two bouts of 30 s supra-maximal cycling sprints. The number of 15 s and 30 s bouts was increased by one during every sec training session. The final 3 training sessions consisted of 7 bouts of 15 s and 7 bouts of 30 s supra-maximal cycling sprints. Both training programs led to a marked increase in enzymatic activities related to glycolysis and aerobic metabolism. Although the activity of creatine kinase, pyruvate kinase and lactate dehydrogenase were significantly

elevated compared to baseline in both groups following the training program, peak power and mean power output increased in the LP group only.

McKenna *et al*., (1997) [85] investigated the effects of 7 weeks of sprint training. Six subjects took part in the study. Subjects trained 3 times per week. Training was conducted in a laboratory under supervision and was performed on a Monark cycle ergometer. The flywheel tension was set at 7.5 % body weight and remained constant for the duration of the training program. Each subject pedalled as fast as possible against the flywheel resistance with the pedalling rate decreasing during the bout. Each training session consisted of several bouts of maximal exercise for 30 sec separated by 4 min recovery periods. In the first week, four bouts per session were used with 4 min of recovery. The number of bouts was increased by two per session each week, up to ten per session at week 4, after which the recovery time was shortened by 30 s each week until week 6. Maximal exercise was increased after training with a 13 % increase in total work output and a 14 % decline in power output during maximal cycling.

Ten weeks of in-season high-intensity interval training (2 sessions per week) has been shown to significantly improve maximal aerobic speed and 40 m sprint time in 22 professional male soccer players [86]. The HIIT involved 2-15 sprints of 40 m with 30 sec of passive recovery. Sprints were performed from a standing start.

Helgerud *et al*., (2001) [6] compared the effects of an 8 week HIIT program with the standard exercise training program on a number of performance and match play indices in 19 elite junior soccer players (18.1 ± 0.8 yr). The interval training program was administered

as an extension of the regular training program and involved 4 x 4 min runs at 90-95% max HR with a 3 min jog recovery period. Eight weeks of HIIT training resulted in a significant increase in $\dot{V}O_2$max, lactate threshold, running economy, distance covered in games, number of sprints in games, number of involvements with the ball in games and average work intensity. There was no significant change in VJ performance, squat 1 RM, 10 m and 40 m speed, kicking velocity, kicking precision or quality of passes.

Coaches are continually searching for innovative ways to include exercises in their training programs that mimic the movement pattern of the game. Using a soccer specific ball dribbling track, McMillian *et al*., (2005) [81] examined the physiological adaptations to 10 weeks of high intensity aerobic interval training in addition to normal soccer training, in youth (18.1 ± 0.8 yr) soccer players. Training consisted of 4 min of dribbling a soccer ball around a specifically designed track at 90-95% HRmax interspersed with a 3 min recovery period at 70% HRmax. Maximal aerobic capacity, squat jump and CMJ improved significantly in response to training. There was no significant improvement in body mass, running economy, rate of force development or 10 m sprint time.

2.8 Comparative Analysis - High Intensity Training vs. Endurance Training

Gibala *et al*., (2006) [25] compared the effect of two weeks of low volume sprint-interval training (SIT) and high volume endurance training group (ET) on exercise capacity and molecular and cellular adaptations in skeletal muscle. Recreationally active students who were not engaged in regular training for a particular sporting event undertook 6 training sessions over 14 days, with 1–2 days recovery between each session. The SIT

involved 4-6 repeated 30 sec bouts of maximal cycling efforts, interspersed with 4 min of recovery of rest or light cycling at 30W. The ET group undertook 90–120 min of continuous cycling at an intensity corresponding to 65% $\dot{V}O_2$peak. There were similar but significant decreases in the time required to complete 50 kJ and 750 kJ cycling time trials. There was also a similar but significant increase in glycogen content, muscle buffering capacity and the maximal activity of cytochrome coxidase and cytochrome coxidase subunits II and IV protein content. Training time commitment over 2 weeks was approximately 2.5 h for SIT and approximately 10.5 h for ET. The total training volume was approximately 90% lower for SIT versus ET.

In a follow up study of longer duration (6 weeks) Burgomaster *et al*., (2008) [10] also found that sprint interval training was a time efficient strategy to increase skeletal muscle oxidative capacity and induce specific metabolic adaptations comparable to traditional endurance training in active but untrained males. Weekly time commitment was 67% lower in the SIT than ET (5h versus 27 h). Peak power output elicited during the Wingate test increased by 17% and 7% in the SIT and ET groups, respectively, with no difference at baseline. Mean power output was increased by 7% in the SIT group only.

In young male and female swimmers aged 9-11 years, $\dot{V}O_2$max increased significantly in response to 5 weeks of HIIT and high volume training (HVT). The HIIT group averaged 5.5 km per week and 11.9 km for HVT group. Competition performance in a 2000 m time trial increased significantly following HIIT, but there was no improvement in the HVT [87].

Sperlich *et al*., (2011) [88] compared the effects of 5 weeks of HIIT and HVT on $\dot{V}O_2$max, 1000 m run, sprinting and jumping performance in 14 year old soccer players. Participants trained 4 times per week (1 - 1.5 h) and played 1 game. Each session started with a 5-10 min warm-up involving some soccer specific drills. The HIIT involved bouts of interval training without a soccer ball at >90% HRmax interspersed with 1-3 min jogging at 50-60% HRmax. The total exercise time, including rest, did not exceed 30 min. The HVT group undertook 45–60 min training sessions at 50–70% HRmax without playing soccer. $\dot{V}O_2$max increased significantly and 1000 m time decreased significantly in the HIIT group only. Sprint performance improved significantly in both groups and there was no change in jumping performance.

Eddy *et al*., (1977) [89] reported a similar increase in $\dot{V}O_2$max, endurance and endurance performance in response to 7 weeks of continuous cycling training (CT) and interval cycling training (IT) in men and women. The CT group trained 4 d/week at 70% $\dot{V}O_2$max. The IT group trained with an interval training method at 100% $\dot{V}O_2$max. The duration of each training session was assigned so that participants completed 10,000 kpm of work per session during the first week and the workload was increased by 3000 kpm/wk.

Tuimil *et al*., (2011) [90] examined the effects of 8 weeks of continuous and interval running (IT) on endurance performance and jump capacity in physically active men. The IT and CT group trained at 90-100% and 65-70% maximal aerobic speed (MAS), respectively. MAS improved significantly and similarly for both groups and CMJ did not change significantly in either group.

Enoksen *et al*., (1999) [91], compared the effect of 10 weeks of high-volume low-intensity training (HVLI) and high-intensity low-volume (HILV) training on $\dot{V}O_2max$, $v\dot{V}O_2max$, running economy, lactic threshold velocity and running performance in well-trained male middle-distance runners (19.9 ± 6.1 yrs). Participants trained 6 days per week with the HVLI and HILV groups running 70 and 50 km/wk, respectively. The HILV group performed 33% of the total training volume at 82-92% HRmax, and 67% at 65-82% HRmax. The HVLI group performed 13% of the total training volume at 82–92% HRmax, and 87% at 65-82% HRmax. Furthermore, the HILV group performed 3 intensive workouts per week at 82–92% of HRmax, and HVLI group performed 1 intensive workout per week. There were no significant differences in any of the measured parameters between the two groups before and after the intervention period. Both groups had a significant improvement in running economy compared to pre training values.

In recreationally active young men and women, 6 weeks of combined endurance and interval training significantly increased $\dot{V}O_2max$ and running velocity at maximal lactate steady state, lactate threshold and blood lactate concentration of 3 mmol/l [92]. Similarly, Jones *et al*,. (1999) [93] found significant improvements in running economy, lactate threshold and $\dot{V}O_2max$ in college aged students in response to a 6 week combined continuous and interval running at an intensity close to lactate threshold (LT).

2.9 Summary

Gaelic football is an amateur sport and players give up a substantial amount of their time for training and competitive games. At club level, HVET appears to be the most

common training method for developing aerobic capacity. Although HVET results in significant improvements in aerobic capacity [7–9] , it is time consuming and may lack the specificity required to maintain or improve indices of speed and power that are required for optimal performance. There is now substantial evidence that HIIT is a more time efficient training method than HVET for improving $\dot{V}O_2$max and endurance performance. In addition, 4-8 [100] sessions of HIIT has been found to maintain or improve peak power output. Surprisingly, no study has simultaneously compared the effect of HVET and HIIT on $\dot{V}O_2$max, speed, and power in club level Gaelic football players or other invasion team sports.

CHAPTER III

METHODOLOGY

3.1 Participants

Twenty five apparently healthy men between the ages of 18 – 35 years currently playing Gaelic football at club level volunteered to participate in the study. Each player had a minimum of 3 years playing experience. During the season they trained on average 2 days per week and played a game on most weekends. Participants were excluded if they were current smokers, had unstable angina, uncontrolled hypertension (systolic blood pressure (BP) >180 mmHg, diastolic BP >100 mmHg), resting tachycardia or unstable/acute heart failure or had any other medical conditions that contraindicated exercise participation.

Individuals who met the entry criteria and who received medical clearance to participate were randomly assigned to the HVET group (n = 12) or HIIT (n = 13) group. The nature and risks of the study were explained and written informed consent was obtained from each participant (Appendix I). The experimental procedures were approved by the Research Ethics Committee at Dublin City University, Ireland.

3.2 Study Design

The study took place in the School of Health and Human Performance at DCU and the DCU Sports Grounds. The training program was undertaken 3 d/week for 6 weeks. Participant's made 2 separate visits to the Human Performance Laboratory, before the study and at the end of the 6 week training program. Each visit was separated by at least 24 h.

3.3 Study Visits

During visit 1 the participants completed a physical activity readiness questionnaire (PAR-Q), a general health questionnaire (Appendix II), had their blood pressure, height and body mass measured. A muscle biopsy was taken from the vastus lateralis, midway between the upper pole of the patella and the anterior superior iliac spine at the anterior border of the iliotibial band using the percutaneous needle biopsy technique described by Bergstrom[94]. The muscle biopsy samples were not used in the present study. Participants then underwent 6 x 10 sec Wingate tests. Participants fasted for 4 h, and refrained from strenuous physical activity for 24 h prior to the visit. During the second visit participants performed a countermovement jump, a vertical jump, had their 5 m and 20 m running speeds assessed and underwent a treadmill exercise test to assess their maximal aerobic capacity ($\dot{V}O_2max$).

3.4 High Volume Endurance Training Program (HVET)

Participants ran on a treadmill (Woodway ELG 55, Waukesha, WI) at 75% $\dot{V}O_2max$. During week 1 and 2, participants ran for 40 min, and the duration was increased to 50 min for the remaining four weeks of training.

3.5 High Intensity Interval Training (HIIT) Protocol

Participants sprinted 100 m (50 m out and 50 m back) followed by a 50 m (25 m out and 25 m back) easy jog (Figure 3.1). Each sprint and recovery period was 40 sec in duration. On average, participants completed the 100 m sprint in 17-20 sec, allowing for 20-23 sec recovery period. A single set was comprised of 4 x 100 m sprints interspersed with a 50 m jog recovery. Each set was followed by a 3 min recovery period. Participants completed 3 sets (12 sprints) during the training sessions in week 1 and 2, and the number of sets was increased to 4 for the remaining 4 weeks of the study.

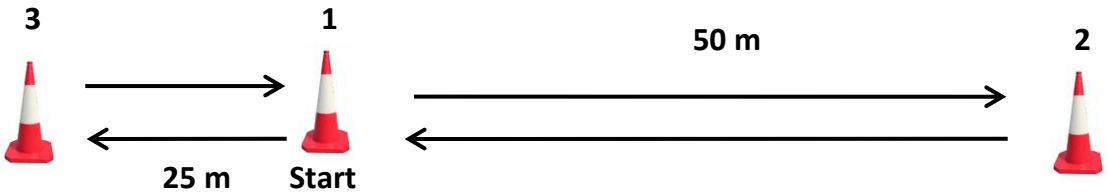

Figure 3.1: HIIT training protocol

3.6 Laboratory Procedures

3.6.1 Vertical Jump

The vertical jump was performed on a FSL JumpMat (FSL, Cookstown, UK) (Figure 3.2 A). Participants stood on the JumpMat with their feet shoulder width apart and arms hanging loosely. When instructed, participants moved into a semi-squat position and then jumped as high as possible, landing on the mat. They were encouraged to use their arms to help propel their body upwards (Figure 3.2 B). Three trials were performed interspersed with a 20 sec rest period and the best score was recorded for statistical analysis.

The FSL JumpMat consists of a hand held electronic timer connected to a contact mat (Tapeswitch Signal Mat, model CVP 1723, Tapeswitch, Farmingdale, NY) measuring 584 x 432 x 2 mm. The system resolution is 1000 Hz with a threshold for operation of 2.3 kg. Jump height is calculated using the formula; h=g·t2/8 (where h is the jump height in metres; g is gravitation acceleration [9.81 $m \cdot s^{-2}$]; t is the flight time in sec)[95]

Figure 3.2: (A) FSL JumpMat (B) Vertical jump technique

3.6.2 Countermovement Jump

Countermovement Jump was performed using the FSL JumpMat (FSL, Cookstown, UK). Participants stood on the JumpMat with their feet shoulder width apart and hands placed on the hips. When instructed, participants moved into a semi-squat position and then jumped as high as possible and landed on the mat (Figure 3.3). Participants were instructed to keep their hands on their hips throughout the jump. Three trials were performed with a 20 sec rest period between each trial. The best score was recorded for statistical analysis.

Figure 3.3: Countermovement jump

3.6.3 5 m and 20 m sprint

SMARTSPEED wireless electronic timing gates (Fusion Sport International) were used to measure 5 m and 20 m running speeds. The timing gates were placed at the start line and at 5 m and 20 m. Participants were instructed to start with their preferred foot forward and placed it 50 cm behind the start line. The SMARTSPEED system has a special error correction technology that is programmed to interpret all events as an individual passes through the light beam. Timing commenced automatically when a player's torso passed through the beam that dissected the start line. Participants commenced each sprint of their own volition and were encouraged to complete the 20 m run in the fastest possible time (Figure 3.4). Following a familiarization practice, each participant performed 3 trials interspersed with a 2 min recovery period. The fastest 5 m and 20 m times were recorded to the nearest millisecond and were used for statistical analysis. Prior to the speed tests, participants performed a 5-10 min warm up that involved progressing from low to high intensity running and included a number of accelerations. In addition, they performed a static stretching routine that incorporated the major muscle groups.

Figure 3.4: SMARTSPEED electronic timing gates

3.6.4 Wingate Test

The Wingate test was undertaken on a Monark 894E cycle ergometer (Monark, Varberg, Sweden). The ergometer was calibrated prior to each test. Participants undertook a 5 min sub maximal warm-up at a self-selected intensity against zero resistance. The warm-up was followed by a 3 min recovery period during which participants were permitted to dismount the bike and stretch.

During the first 5 sec of the test, participants cycled at 90 rpm against zero resistance. Following a 5 sec countdown a resistance equal to 7.5% of participant's body mass was applied after which they exercised maximally for 10 sec. Participants were instructed to remain seated throughout the testing procedure. A total of 6 Wingate tests were performed, and each test was separated by 50 sec of self-regulated active recovery (Figure 3.5). Verbal encouragement was given throughout each trial. Following completion of the test, participants continued cycling against zero resistance for 2-3 min to assist recovery.

Peak power, mean power and the power drop were measured. Peak power (PP) is the maximum power exerted during a 5 sec period and was calculated using the formula; PP (kgm·5 sec^{-1}) = rev (max) in 5 sec x D·rev^{-1} sec x F, where D is the distance travelled by the flywheel in 1 revolution (6 m), and F is the force setting in kg. Mean power (MP) is the average power exerted during the 30 sec work bout and is calculated using the formula; MP (kg 30 sec^{-1}) = rev (total) in 30 sec x D·rev^{-1} sec x F, where D is the distance travelled by the flywheel in 1 revolution (6 m), and F is the force setting in kg. The fatigue index (FI) is the percentage of peak power drop off during the 30 sec test and is calculated using the formula; FI (%) = [1 - (lowest power kgm kg 5 sec^{-1}/ lowest power kgm kg 5 sec^{-1})] x 100.

Figure 3.5: Wingate test

3.6.5 Maximal Aerobic Capacity

Maximal aerobic capacity was determined on a treadmill (Woodway ELG 55, Waukesha, WI). Participants warmed up at 8 $km \cdot h^{-1}$ for 3 min at 1% gradient. Following the warm-up, the treadmill velocity was increased 1 $km \cdot h^{-1}$ every 3 min until the blood lactate concentration reached 4 $mmol.L^{-1}$. The treadmill velocity was set at 10 $km \cdot h^{-1}$ and the grade at 4%. The speed remained constant and the gradient was increased by 1% every min until the subject reached volitional fatigue. Maximal oxygen uptake was determined by averaging the two highest consecutive 30 sec values. Heart rate, expired oxygen, carbon dioxide and ventilatory volume were continuously recorded. (Figure 3.6)

Figure 3.6: Maximal aerobic capacity test

3.6.6 Cardiorespiratory and Metabolic Measures

Respiratory metabolic responses were determined using standard open-circuit spirometry techniques (Sensormedics Vmax 229, SensorMedics Corp., CA). Prior to testing, the gas analyzers were calibrated with standard gases of known concentration.

3.6.7 Mass Flow Sensor Heated wire Anemometer-Mode of Operation

A mass flow sensor (Sensormedics, Loma Linda, CA, USA) was used to collect breath-by-breath measurement of ventilation. The mass flow sensor is a low resistance tube with a tapered internal diameter extending from both ends of a laminar flow throat. Cold and hot stainless steel wires electrically heated to -180°C and -240°C respectively, are centered in the flow stream. These wires are elements in a servo-controller bridge circuit that maintains the resistance ratio of the two wires at a constant value. If only the temperature of the inspired gases changes, then both wires lose heat at the same rate and no current change is required to keep the bridge balanced. As air flows across the wires, the hot air loses heat more rapidly than the cold air and the current must be added to keep the bridges balanced at a 3:4 ratio. The amount of current required is proportional to the mass flow of the gas. This method ensures that the sensor measures only the heat loss from the molecular convection of the moving gas stream and not the artifact due to cooling of the gas as it passes through a breathing assembly.

The mass flow meter responds to instantaneous flow rates between 0-16 $L.sec^{-1}$ and integrated flow between 0-350 $L \cdot min^{-1}$, with flow resistance <1.5 $cmH_2O \cdot L^{-1} \cdot sec^{-1}$. The

mass flow sensor was outputted to the analyser module of the Vmax 229 and was sampled at a rate of 125 Hz.

3.6.8 Mass Flow Sensor Calibration

A 3 litre volume syringe (Sensormedics, Loma Linda, CA, USA) was used to calibrate the mass flow sensor prior to each test. The syringe was connected to the mass flow sensor and stroked four times in order to measure inspired and expired volumes. The volumes were calculated by expressing 3l as a fraction of each measured inspired and expired volume achieved during calibration. An average correction factor was calculated for inspired and expired volumes and used to fine tune the volume measurement.

A verification procedure was performed. This involved stroking the 3l volume syringe four times. Inspired and expired volumes were measured using the newly calculated correction factors. In order to pass the calibration procedure, one of the four strokes had to have an average flow rate < 0.5 $L.sec^{-1}$ and at least one of the four strokes had to have an average flow > 3.0 $L.sec^{-1}$.

3.6.9 Gas Analysers

The Vmax 229 utilizes a rapid response infrared measurement technique. An O_2 and CO_2 analyser is integrated with the Vmax 229. A small sample of inspired air is drawn through a sample cell and exposed to an infrared light through an optical that is passed through a band pass filter and the sample cell. An infrared detector responds to the amount of infrared light that passes through the sample cell. The amount of light that

passes through the sample cell varies according to the concentration of CO_2 in the sample cell. Based on measured levels of infrared light intensity, the analyser computes the PCO_2 in the gas sample. The CO_2 analyser is linearly scaled across the 0-100% range with a resolution of 0.01% CO_2 and a response time of < 130 ms (10-90%) at 500 $ml.min^{-1}$ flow. The O_2 analyser is based on the high paramagnetic susceptibility of O_2. A diamagnetic glass dumbbell suspended in a magnetic field rotates in proportion to the PO_2. The analyser is linearly scaled across the 0-100% range with a resolution of 0.01% O_2 and a response time of < 130 ms (10-90%) at 500$ml.min^{-1}$ flow.

3.6.10 Calibration of CO_2 and O_2 Analysers

The gas analysers were calibrated with standard gases of known concentration (BOC gases, Dublin, Ireland). The first calibration gas contained 26.00 ± 0.02% oxygen and the balance nitrogen (N_2). The second calibration gas contained 4.00 ± 0.02% carbon dioxide, 16.00 ± 0.02% O_2, and the balance N_2. A small bore drying tube connected to the CO_2 and O_2 analysers sampled the calibration gases. The absorption and evaporative properties of the drying tube ensured that the relative humidity of the calibration gas was equilibrated to ambient conditions prior to sampling by the O_2 and CO_2 analysers. The calibration gas was sampled at a rate of 125 Hz. The response time was similar between O_2 and CO_2 analyser.

3.7 Statistical Analysis

Prior to statistical analysis the data was checked for normality using the Shapiro-Wilk test. A group (HVET and HIIT) x time (baseline and week 6) repeated measures ANOVA was

used to compare the mean differences within and between groups. Significant main effects were probed using a Bonferroni post hoc test. The relation between selected dependent variables was established using Pearson's product moment correlation. SPSS for Windows statistical software (ver 19.0) was used to perform the statistical analysis. Statistical significance was accepted at the $p < 0.05$ level of confidence.

CHAPTER IV

RESULTS

The physical characteristics of the participants are summarized in table 4.1. There was no significant change in any of the measured anthropometric parameters, maximal minute ventilation, or blood lactate levels in either the HIIT or HVET group in response to training (Table 4.1).

4.1 Maximal Aerobic Capacity

Compared to baseline, $\dot{V}O_2$max and $v\dot{V}O_2$max increased significantly in both the HIIT and HVET groups following the 6 week training program. Maximal heart rate was significantly lower at week 6 than baseline in both the HIIT and HVET group.

Table 4.1: Physical and physiological characteristics

	Group			
	HIIT		HVET	
	Pre-Training	Post Training	Pre-Training	Post Training
Age (y)	27.2 ± 3.6	27.2 ± 3.6	24.7 ± 4.0	24.7 ± 4.0
Height (cm)	1.8 ± .07	1.8 ± .07	1.8 ± .04	1.8 ± .04
Weight (kg)	79.7 ± 9.6	79.7 ± 9.8	76.6 ± 9.7	76.6 ± 10.4
BMI ($kg \cdot m^{-2}$)	25.3 ± 1.5	25.3 ± 1.5	23.6 ± 2.8	23.5 ± 2.9
Body Fat (%)	16.9 ± 4.6	16.2 ± 5.0	13.5 ± 4.3	13.0 ± 4.6
$\dot{V}O_2$max ($ml/kg.min^{-1}$)	52.5 ± 5.3	56.0 ± 4.7 *	52.8 ± 5.5	56.4 ± 4.1*
Ventilation (L/min)	108.5 ± 10.3	115.6 ± 18.1	111.8 ± 16.6	116.5 ± 13.7
Heart rate (beats/min)	197.7 ± 7.9	192.0 ± 7.6†	196.8 ± 6.7	193.6 ± 5.6*
RPE-O	18.1 ± 1.8	19.1 ± 1.0*	18.9 ± 1.3	18.9 ± 1.3
Lactate (mmol/L)	7.5 ± 2.5	8.4 ± 2.2	7.6 ± 2.3	8.4 ± 1.6
$v\dot{V}O_2$max (km/h)	14.1 ± 1.2	15.1 ± 1.7*	13.7 ± 1.0	15.3 ± 2.3†

Values are means ± SD; *$p < 0.05$ vs. pre-training, †$p < 0.01$ vs. pre-training

4.2 Speed and Power

Participants` speed and power at baseline and following the 6 week training program are presented in Table 4.2. There was no significant change in CMJ, CMJ flight time or 5m speed in either the HIIT or HVET group in response to training. Compared to baseline, VJ and VJ flight time decreased significantly in the HVET group following the 6 week training program and did not change in the HIIT group. Compared to baseline, 20m speed increased significantly in the HVET group following the 6 week training program and did not change in the HIIT group.

Table 4.2: Speed and power results

	Group			
	High Intensity Training		**Endurance Training**	
	Pre-Training	Post Training	Pre-Training	Post Training
CMJ (cm)	35.9 ± 5.8	34.6 ± 3.5	33.7 ± 5.1	33.1 ± 4.9
CMJ Flight Time (s)	0.5 ± 0.04	0.5 ± 0.03	0.5 ± 0.04	0.5 ± 0.04
Vertical Jump (cm)	39.5 ± 6.2	38.3 ± 3.7	38.5 ± 5.7	36.3 ± 4.9*
Vertical Jump Flight Time (s)	0.6 ± 0.04	0.6 ± 0.03	0.6 ± 0.04	0.5 ± 0.03*
5m Time (s)	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1	1.1 ± 0.1
20m Time (s)	3.3 ± 0.2	3.3 ± 0.1	3.2 ± 0.1	3.3 ± 0.1†

Values are means ± SD; *$p < 0.05$ vs. pre-training, †$p < 0.01$ vs. pre-training

4.3 Wingate Test

Participants` Wingate scores at baseline and following the 6 week training program are presented in Table 4.3. Average power output at baseline was significantly higher in HIIT than HVET during Wingate trial 4, 5 and 6. Peak power output at baseline was significantly higher in HIIT than HVET during Wingate trial 5 and 6. The drop in power output (fatigue index) was significantly greater in HIIT than HVET during trial 5 at baseline.

Compared to baseline, average power and peak power increased significantly in the HVET group during trials 1, 3 and 5, post-training. The fatigue index at week 6 was significantly higher than at baseline in HVET during trial 5. Average power output and peak power output decreased significantly post-training compared to baseline during trial 4 in the HIIT group. Compared to pre-training, there was no significant change in average power output and peak power output during trials 2 and 6, in either HIIT or HVET in response to training. The fatigue index was similar in both the HIIT and HVET during trials 1, 2, 3, 4 and 6 in both the HIIT and HVET before and after training.

Table 4.3: Wingate test results

	Group			
	High Intensity Training		**Endurance Training**	
	Pre-Training	Post Training	Pre-Training	Post Training
Power (w) Trial 1	866.0 ± 144.5	867.6 ± 159.3	798.9 ± 100.8	888.9 ± 152.7†
Power (w) Trial 2	869.4 ± 140.5	842.4 ± 136.4	796.3 ± 97.2	844.3 ± 160.7
Power (w) Trial 3	837.7 ± 120.3	798.4 ± 120.6	748.1 ± 97.0	804.5 ± 132.6*
Power (w) Trial 4	809.3 ± 90.5a	750.2 ±121.0*	715.4 ± 98.1	754.9 ± 122.3
Power (w) Trial 5	770.9 ± 86.0b	735.0 ± 132.3	644.7 ± 92.3	733.1 ± 131.1*
Power (w) Trial 6	751.0 ± 105.7a	707.0 ± 128.0	653.9 ± 102.8	695.9 ± 130.2
Peak Power (w/kg) Trial 1	11.0 ± 1.2	11.0 ± 1.8	10.5 ± 1.0	11.7 ± 1.1‡
Peak Power (w/kg) Trial 2	11.0 ± 1.3	10.7 ± 1.5	10.5 ± 1.1	11.1 ± 1.0
Peak Power (w/kg) Trial 3	10.7 ± 1.3	10.2 ± 1.5	9.4 ± 1.7	10.6 ± 0.8†
Peak Power (w/kg) Trial 4	10.4 ± 1.3	9.6 ± 1.5*	9.4 ± 1.0	10.0 ± 1.0
Peak Power (w/kg) Trial 5	9.9 ± 1.2 **b**	9.4 ± 1.6	8.5 ± 1.0	9.6 ± 1.1*
Peak Power (w/kg) Trial 6	9.6 ± 1.3 **a**	9.0 ± 1.5	8.6 ± 0.9	9.2 ± 1.2
Power Drop (W) Trial 1	236.4 ± 71.3	318.2 ± 180.0	319.9 ± 181.2	292.2 ± 117.3
Power Drop (W) Trial 2	266.0 ± 89.9	291.0 ± 112.2	259.8 ± 64.3	273.5 ± 103.4
Power Drop (W) Trial 3	263.3 ± 78.9	279.6 ± 75.8	259.7 ± 63.7	260.8 ± 64.4
Power Drop (W) Trial 4	268.4 ± 61.1	268.4 ± 87.1	265.0 ± 56.4	254.0 ± 58.3
Power Drop (W) Trial 5	282.7 ± 47.7 b	281.6 ± 85.7	222.4 ± 49.0	268.2 ± 86.4*
Power Drop (W) Trial 6	277.2 ± 52.8	263.9 ± 76.6	244.6 ± 29.4	250.0 ± 52.9

Values are means ± SD; * $p < 0.05$ vs. pre-training, †$p < 0.01$ vs. pre-training; a $p<0.05$ vs. pre HVET group; $p < 0.01$ vs. pre HVET group

4.4 Correlation Analysis

Correlation analysis undertaken at baseline on the combined group data indicated that there was a significant relation between CMJ and VJ ($r= 0.89$, $p<0.001$), CMJ and 20 m run time ($r= -0.559$, $p<0.01$), VJ and 20 m run time ($r= -0.659$, $p<0.001$), and 5 m and 20 m run time ($r= 0.792$, $p<0.001$). There was no significant relation between any of the measured Wingate parameters and CMJ, VJ, 5 m and 20 m sprint time.

CHAPTER V

DISCUSSION

The physiological demands of Gaelic football, like any invasion team sport, are determined in large part by the activity patterns of the game which are largely unpredictable, and are imposed by the pattern of play. The majority of playing time in Gaelic football involves low to moderate levels of activity interspersed with short duration, high intensity efforts involving speed and power.

High volume endurance training involving continuous steady state running has traditionally been used by coaches to develop fitness levels in club level Gaelic football players. This form of training is known to induce both central and peripheral physiological adaptations that result in an increased $\dot{V}O_2max$ [7–9,79]. In addition to supplying the energy for low to moderate intensity activities, a high aerobic capacity helps to ensure the provision of ATP (via oxidative phosphorylation of ADP and AMP) for the replenishment of phosphagen stores following short-duration bouts of high-intensity activities [62], and decreases reliance on anaerobic glycolysis during periods of play that involve repeated high-intensity sprints, with relatively short recovery intervals.

In addition to the large time requirement, a major drawback of this type of continuous steady state endurance training is that it may lack the specificity to maintain or improve indices of speed and power. More recently, HIIT training has been advocated as an alternative to traditional HVET in developing aerobic capacity [10]. A potential advantage of HIIT over HVET is the lower total time requirement [10,25]. In addition, the greater specificity

associated with HIIT may also help to maintain or improve speed and power [87–90]. No previous studies have simultaneously compared the effect of HVET and HIIT on $\dot{V}O_2$max, running speed and muscle power in club level Gaelic football players. It was hypothesised that among club level Gaelic football players, $\dot{V}O_2$max would increase in both training groups, and that selected indices of speed would increase and power would decrease in the HVET group and remain unaltered in the HIIT groups following 6 weeks of training.

The pre-training $\dot{V}O_2$max values in both the HIIT and HVET group were almost identical to values previously reported for GAA club level Gaelic football players [48,96]. $\dot{V}O_2$max values ranging from 49 to 59 $ml \cdot kg^{-1} \cdot min^{-1}$ have been reported for inter-county players [31,47,48]. However, the majority of values have been estimated from a progressive 20 m shuttle run test [31,97]. In the present study $\dot{V}O_2$max increased significantly in both the HVET and HIIT group in response to the 6 week training program, and the percentage improvement was similar (7%) in both groups.

An individual's response to exercise training depends on the interaction between hereditary, age, gender and environment. The genetic factors establish the limit for each individual, but training can push $\dot{V}O_2$max to the upper limits of these boundaries. Studies involving monozygous and dizygous twins have found that genetics may account for approximately 25-50% of the variance in $\dot{V}O_2$max values [98,99]. In general, an average improvement of between 5% and 25% can be anticipated for healthy young adults in response to HVET ranging from 2 -25 weeks [7–9,79]. HIIT has been shown to induce a number of biochemical changes that have been associated with improvements in $\dot{V}O_2$max. These

include an increase in muscle oxidative capacity, muscle buffering capacity and nuclear abundance of PGC-1α, a transcriptional co-activator which plays a crucial role in co-ordinating mitochondrial gene transcription [10,25,80].

A number of laboratory [10,25] and field based studies [6,81,88] have shown HIIT to be an effective training strategy for improving $\dot{V}O_2$max. Sperlich *et al*., (2011) [88] found a 7% increase in $\dot{V}O_2$max in response to 5 weeks of HIIT in youth soccer players, and Helgerud *et al*., (2001) [6] reported an 11% increase in $\dot{V}O_2$max in response to an 8 week HIIT program in 19 elite junior soccer players. Both training interventions were administered as an extension of the regular soccer-specific training. Using high intensity cycling, Burgomaster *et al*., (2008) [10] found similar improvements in $\dot{V}O_2$max in response to 6 weeks of endurance training or HIIT despite the greater time commitment involved in the endurance training program. In the present study, the increase in $\dot{V}O_2$max in both training groups was similar despite the fact that the total time requirement was 2.5 fold greater in the HVET than the HIIT group (840 min vs. 374 min). In addition, the total exercise time in the HIIT group was 88 min or 10.5% of the total HVET time (Figure 5.1).

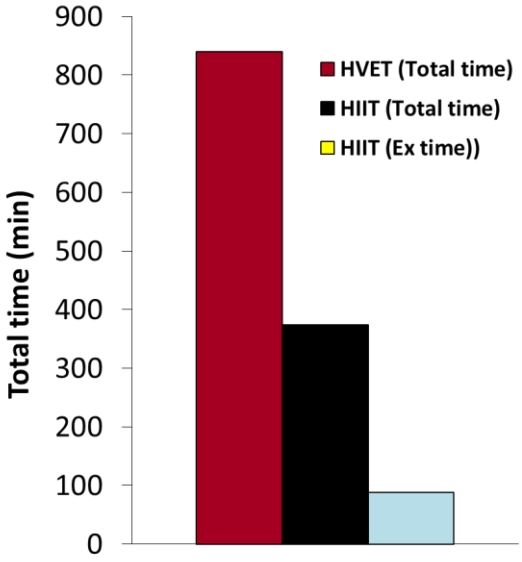

Figure 5.1: Total time commitment in the HVET and HIIT group, and total exercise time commitment in the HIIT (Ex time) group

These findings have important implications for coaches/trainers involved in the preparation of club level Gaelic football teams. Players at club level undertake, on average, 2-3 collective training sessions per week. In addition to increasing fitness levels, this relatively short period for collective training is normally used to improve individual skills and team tactics. The substantial saving in time associated with the HIIT may free up considerable training time that can be used to develop individual skills levels and team tactics while improving maximal aerobic capacity.

Speed and power are important fitness attributes for Gaelic football. It was hypothesised that the measured indices of speed and power would decrease significantly in response to HVET, due to the predominant use of slow twitch motor units. In contrast, it was hypothesised that speed and power would be maintained in response to HIIT due to the additional activation of fast twitch motor units. The time to complete the 20 m sprint

increased significantly and VJ and VJ flight time decreased significantly in the HVET following the 6 week training program. In contrast, there was no significant change in 5 m speed, 20 m speed, VJ or CMJ performance in the HIIT group. It is possible that the speed and jump test performance scores were maintained in the HIIT group following the 6 week training program due, in part, to the fact that both fast twitch type IIa and type IIb muscle fibers were recruited to supply the high force demands during training. Considering that HVET is commonly used in the preparation of players for many invasion field games, it is interesting that relatively few published studies have simultaneously evaluated the effect of this form of training on $\dot{V}O_2$max, speed and vertical jump performance in players involved in invasion team sports. Despite an 11% increase in $\dot{V}O_2$max, Helgerud *et al*., (2001) [6] found no significant change in VJ performance, 10 m and 40 m speed, in response to an 8 week HIIT program in 19 elite junior soccer players. In contrast, McMillan *et al*., (2005) [81] found a significant improvement in both $\dot{V}O_2$max and CMJ performance in professional youth soccer players following 10 weeks of high intensity aerobic interval training. Sperlich *et al*., (2011) [88] found a significant improvement in sprint performance in adolescent soccer players in response to 5 weeks of both HIIT and high volume training. However, $\dot{V}O_2$max increased significantly in the HIIT group only.

In this study, the 6 week HVET program resulted in a significant decrease in VJ performance, VJ flight time and 20m speed. Muscle fibre recruitment is determined by force requirements, with the slow muscle fibres being activated for low force contractions and increasingly fast muscle fibres being additionally activated to supply greater force demands. It is possible that the HVET involved recruitment of primarily slow twitch motor

units and fast twitch IIa. Muscle fibres display considerable plasticity in relation to their biochemical and morphological properties when exposed to different functional demands. Endurance training appears to induce fibre type remodelling resulting in type IIa fast twitch fibres taking on the morphologic and biochemical characteristics of slow twitch fibres. These adaptations, although beneficial for improving endurance exercise performance, do not provide the desired loading for type IIb fibres to maintain speed and power.

With a few exceptions, peak power, average power and the fatigue index assessed during the Wingate test did not change in the HIIT group in response to the 6 week training program. Average power and peak power were significantly higher in the HVET group during trials 1, 3 and 5, at week 6. In contrast, Burgomaster *et al*, (2008) [10] found that 6 weeks of cycling sprint interval training (SIT) and ET increased peak power output during the Wingate test by 17% and 7% in the SIT and ET groups respectively with no difference between groups whereas, mean power output was increased by 7% in the SIT group only. Peak power and mean power output also increased following 6-7 weeks of high intensity interval training involving 30 sec Wingate tests [18,84]. Zieman *et al*, (2011) [83] found a significant increase in mean power, peak power, and $\dot{V}O_2$max, in physically active men following 6 weeks of interval training consisting of 6 x 90 s bouts of cycling at 80% $\dot{V}O_2$max interspersed with 180 s rest period, 3 times per week. Lack of testing specificity may help to explain the different findings. The fact that maximal power output during the Wingate test was not related to performance in any of the jump tests or sprint tests may indicate that the Wingate test is not sensitive enough to measure power and speed during weight bearing exercise.

In summary, this is the first study to assess the effects of two different training programs on $\dot{V}O_2$max and indices of speed and power in club level Gaelic football players. The present findings indicate that HIIT is a more effective and time efficient strategy than HVET to improve aerobic capacity and maintain or improve speed and power in club level Gaelic football players.

5.1 Study Limitations

1. Only linear speed was measured. Future, studies should examine the effect of HIIT and HVET on multi-directional speed involving acceleration and deceleration

2. The fact that only club level players participated in the study limits its external validity

3. It was not possible to determine whether the improvements in $\dot{V}O_2$max in the HIIT and HVET group were due to central or peripheral adaptations, or a combination of both

CHAPTER VI

CONCLUSIONS

It appears that HIIT is a more effective and time efficient training method than HVET for improving aerobic capacity and maintaining speed and power in club level Gaelic football players. In agreement with our stated hypothesis, there was a similar increase in aerobic capacity in both the HIIT and HVET groups following 6 weeks of training. It was also hypothesized that 5 m and 20 m running speed would increase and CMJ and VJ would decrease significantly in club level Gaelic football players following 6 weeks of HVET. In contrast, it was hypothesized that both speed and power would remain unchanged following 6 weeks of HIIT. Although performance in the 5 m sprint and CMJ were unchanged following the HVET program, the time required to complete the 20 m speed test increased significantly and performance in the VJ test decreased significantly. All measured indices of speed and power were maintained in the HIIT group. These findings indicate that HVET is appropriate for the development of aerobic capacity but lacks the specificity required to maintain 20 speed and VJ performance. The fact that peak power output and mean power output during the Wingate test were not related to performance in any of the jump tests or sprints test indicates that the Wingate test may lack specificity for field based sports.

6.1 Recommendations for Future Research

- Examine the most appropriate HIIT work to rest ratio for simultaneously improving or maintaining aerobic capacity and indices of speed and power in Gaelic football players

- Examine the effects of shorter duration HIIT and HVET involving running on aerobic capacity and indices of speed and power in Gaelic football players

- Compare the effects of short periods of HIIT and HVET involving running on aerobic capacity and indices of speed and power among inter-county level senior Gaelic football players.

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APPENDIX 1 – Ethics Submission

Dublin City University
RESEARCH ETHICS COMMITTEE

APPLICATION FOR APPROVAL OF A PROJECT INVOLVING **HUMAN PARTICIPANTS**

Application No. *(office use only)* DCUREC/2010/ ☐☐☐

Period of Approval *(office use only)* ...../...../..... to .....

This application form is to be used by researchers seeking ethics approval for individual projects and studies. The **signed original and an electronic copy** of your completed application must be submitted to the DCU Research Ethics Committee.

NB - The hard copy must be signed by the PI. The electronic copy should consist of one file only, which incorporates all supplementary documentation. The completed application must be proofread and spellchecked before submission to the REC. All sections of the application form should be completed. Applications which do not adhere to these requirements will not be accepted for review and will be returned directly to the applicant.

Applications must be completed on the form; answers in the form of attachments will not be accepted, except where indicated. No handwritten applications will be accepted. **Research must not commence until written approval has been received from the Research Ethics Committee.**

PROJECT TITLE	**Muscle adaptations in response to low volume high intensity interval training and endurance training in Gaelic games players**
PRINCIPAL INVESTIGATOR(S)	**Prof. Niall Moyna**

Please confirm that **all** supplementary information is included in your application (in both signed original and electronic copy). If questionnaire or interview questions are submitted in draft form, a copy of the final documentation must be submitted for final approval when available.

	INCLUDED		NOT APPLICABLE
Bibliography	☒		☐
Recruitment advertisement	☒		☐
Plain language statement/Information Statement	☒		☐
Informed Consent form	☒		☐
Evidence of external approvals related to the research	☐		☒
Questionnaire	☐ draft	☐ final	☒

Interview Schedule	☐ draft	☐ final	☒
Debriefing material	☐		☒
Other	☐		☒

Please note:

1. Any amendments to the original approved proposal must receive prior REC approval.

2. As a condition of approval investigators are required to document and report immediately to the Secretary of the Research Ethics Committee any adverse events, any issues which might negatively impact on the conduct of the research and/or any complaint from a participant relating to their participation in the study

Please submit the **signed original, plus the electronic copy** of your completed application to:
Ms. Fiona Brennan, Research Officer, Office of the Vice-President for Research
(fiona.brennan@dcu.ie, Ph. 01-7007816)

Guidelines to Applicants

1.1 PRINCIPAL INVESTIGATOR(S): *The named Principal Investigator is the person with primary responsibility for the research project. Doctoral researchers and Research Masters or their supervisors may be listed as Principal Investigators, depending on the conventions of the discipline and on the individual case. It should be made clear, in subsequent sections of this application, who is carrying out the research procedures. In the case of Taught Masters and undergraduate student projects the supervisors are Principal Investigators.*

2.0 PROJECT OUTLINE: *Provide a brief outline of the project, aims, methods, duration, funding, profile of participants and proposed interaction with them. This description must be in everyday language that is free from jargon. Please explain any technical terms or discipline-specific phrases.*

2.1 LAY DESCRIPTION: *Provide a brief outline of the project, including what participants will be required to do. This description must be in everyday language which is free from jargon. Please explain any technical terms or discipline-specific phrases. (No more than 300 words).*

2.2 AIMS OF AND JUSTIFICATION FOR THE RESEARCH: *State the aims and significance of the project (approx. 400 words). Where relevant, state the specific hypothesis to be tested. Also please provide a brief description of current research, a justification as to why this research should proceed and an explanation of any expected benefits to the community.* ***NB – all references cited should be listed in an attached bibliography.***

2.3 PROPOSED METHOD: *Provide an outline of the proposed method, including details of data collection techniques, tasks participants will be asked to do, the estimated time commitment involved, and how data will be analysed. If the project includes any procedure which is beyond already established and accepted techniques please include a description of it. (No more than 400 words.)*

2.4 PARTICIPANT PROFILE: *Provide number, age range and source of participants. Please provide a justification of your proposed sample size. Please provide a justification for selecting a specific gender.*

2.5 MEANS BY WHICH PARTICIPANTS ARE TO BE RECRUITED: *Please provide specific details as to how you will be recruiting participants. How will people be told you are doing this research? How will they be approached and asked if they are willing to participate? If you are mailing to or phoning people, please explain how you have obtained their names and contact details. This information will need to be included in the plain language statement. If a recruitment advertisement is to be used, please ensure you attach a copy to this application.*

3.3 POTENTIAL RISKS TO PARTICIPANTS AND RISK MANAGEMENT PROCEDURES*: Identify, as far as possible, all potential risks to participants (physical, psychological, social, legal or economic etc.), associated with the proposed research. Please explain what risk management procedures will be put in place.*

3.6 ADVERSE/UNEXPECTED OUTCOMES: *Please describe what measures you have in place in the event that there are any unexpected outcomes or adverse effects to participants arising from involvement in the project.*

3.7 MONITORING: *Please explain how you propose to monitor the conduct of the project (especially where several people are involved in recruiting or interviewing, administering procedures) to ensure that it conforms with the procedures set out in this application. In the case of student projects please give details of how the supervisor(s) will monitor the conduct of the project.*

3.8 SUPPORT FOR PARTICIPANTS: *Depending on risks to participants you may need to consider having additional support for participants during/after the study. Consider whether your project would require additional support, e.g., external counselling available to participants. Please advise what support will be available.*

4.0 INVESTIGATORS' QUALIFICATIONS, EXPERIENCE AND SKILLS: *List the academic qualifications and outline the experience and skills relevant to this project that the researchers and any supporting staff have in carrying out the research and in dealing with any emergencies, unexpected outcomes, or contingencies that may arise.*

5.2 HOW WILL THE ANONYMITY OF THE PARTICIPANTS BE RESPECTED? *Please bear in mind that where the sample size is very small, it may be impossible to guarantee anonymity/confidentiality of participant identity. Participants involved in such projects need to be advised of this limitation.*

5.3 LEGAL LIMITATIONS TO DATA CONFIDENTIALITY: *Participants need to be aware that confidentiality of information provided can only be protected within the limitations of the law - i.e., it is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professions. Depending on the research proposal you may need to specifically state these limitations.*

6.0 DATA/SAMPLE STORAGE, SECURITY AND DISPOSAL: *For the purpose of this section, "Data" includes that in a raw or processed state (e.g. interview audiotape, transcript or analysis). "Samples" include body fluids or tissue samples.*

8.0 PLAIN LANGUAGE STATEMENT: *Written information in plain language that you will be providing to participants, outlining the phases and nature of their involvement in the project and inviting their participation. Please note that the language used must reflect the participant age group and corresponding comprehension level.*

9.0 INFORMED CONSENT FORM: *This is a very important document that should be addressed by participants to researchers, requiring participants to indicate their consent to specific statements, and give their signature.*

FOR FURTHER INFORMATION AND NOTES ON THE DEVELOPMENT OF PLAIN LANGUAGE STATEMENTS AND INFORMED CONSENT FORMS, PLEASE CONSULT THE DCU REC WEBSITE: WWW.DCU.IE/RESEARCH/ETHICS

1. ADMINISTRATIVE DETAILS

THIS PROJECT IS: *(tick as many as apply)*

- ☐ Research Project
- ☐ Practical Class
- ☐ Funded Consultancy
- ☐ Clinical Trial
- ☒ Student Research Project *(please give details)*
  - ☒ Research Masters
  - ☐ Taught Masters
  - ☒ PhD
  - ☒☐ Undergraduate
- ☐ Other - *Please Describe:*

Project Start Date: **September 2010**

Project End date: **December 2011**

1.1 INVESTIGATOR CONTACT DETAILS

PRINCIPAL INVESTIGATOR(S):

TITLE	*SURNAME*	*FIRST NAME*	*PHONE*	*FAX*	*EMAIL*
Prof	Moyna	Niall	7008802	7008888	niall.moyna@dcu.ie

OTHER INVESTIGATORS:

TITLE	*SURNAME*	*FIRST NAME*	*PHONE*	*FAX*	*EMAIL*
Dr.	McCaffrey	Noel	0872797597	7008888	noel.mccaffrey@dcu.ie
Dr.	Susta	Davide		7008888	davide.susta@dcu.ie
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Mr.	Cregg	Cathal	0877633021	7008888	cathal.cregg2@mail.dcu.ie
Mr.	Kelly	David	0851618207	7008888	david.kelly59@mail.dcu.ie

FACULTY/DEPARTMENT/SCHOOL/ CENTRE: School of Health and Human Performance

1.2 WILL THE RESEARCH BE UNDERTAKEN ON-SITE AT DUBLIN CITY UNIVERSITY?

☒ YES ☐ NO

1.3 IS THIS PROTOCOL BEING SUBMITTED TO ANOTHER ETHICS COMMITTEE, OR HAS IT BEEN PREVIOUSLY SUBMITTED TO AN ETHICS COMMITTEE?*)*

☐ YES ☒ NO

DECLARATION BY INVESTIGATORS

The information contained herein is, to the best of my knowledge and belief, accurate. I have read the University's current research ethics guidelines, and accept responsibility for the conduct of the procedures set out in the attached application in accordance with the guidelines, the University's policy on Conflict of Interest and any other condition laid down by the Dublin City University Research Ethics Committee or its Sub-Committees. I have attempted to identify all risks related to the research that may arise in conducting this research and acknowledge my obligations and the rights of the participants.

If there any affiliation or financial interest for researcher(s) in this research or its outcomes or any other circumstances which might represent a perceived, potential or actual conflict of interest this should be declared in accordance with Dublin City University policy on Conflicts of Interest.

I and my co-investigators or supporting staff have the appropriate qualifications, experience and facilities to conduct the research set out in the attached application and to deal with any emergencies and contingencies related to the research that may arise.
Signature(s):

Principal investigator(s): Niall Moyna

Print name(s) in block letters: *Niall Moyna*

Date: *3/9/2010*

2. PROJECT OUTLINE

2.1 LAY DESCRIPTION

Endurance training predominates in intermittent type sports such as Gaelic games in which aerobic fitness is essential (1). Recent studies have shown that brief repeated sessions of 'all-out' high intensity or sprint type interval training (SIT) induce changes in skeletal muscle metabolism that resemble endurance type (ET) training (3;4). Most of the studies which confirm these findings are based on untrained subjects who trained on a stationary bike in a laboratory (4, 5). The purpose of this study is to compare the effect of 6 weeks (3 d/week) of SIT with 6 weeks (3 d/week) of ET on measures of fitness and performance in trained and untrained Gaelic football players. The total training time will be approximately 11 h 33 min and 13.4 min for the ET and SIT respectively. A total of 20 trained (T) and 20 untrained (U) subjects will be randomly assigned to an endurance training group (ET) or a high intensity interval training group (HIIT). Before and after the 6 week training program the subjects will have a muscle biopsy and blood sample taken and will undergo a number of tests to measure body composition, speed, power, agility, lactate threshold, aerobic capacity, anaerobic capacity, and endurance performance. Blood lactate levels will be measured before and immediately after the third weekly training session. The results of the study may have significant implications for training guidelines for Gaelic football.

2.2 AIMS OF AND JUSTIFICATION FOR THE RESEARCH

Aims of the Research:

To compare the effect of 6 weeks of SIT and ET on speed, power, agility, maximal aerobic capacity, anaerobic capacity, intermittent endurance capacity, muscle oxidative capacity and selected measures of whole body and skeletal muscle substrate metabolism in trained and untrained Gaelic football players. The total training will be 11 h 33 min and 13.4 min for the SIT and ET group respectively.

Justification:

Endurance training induces numerous physiological and metabolic adaptations that improve endurance capacity (2). Although this type of training offers significant training adaptations it requires a large time commitment. Recent studies have shown that brief repeated sessions of 'all-out' high intensity or sprint type interval training (SIT) induces changes in skeletal muscle energy metabolism that resemble endurance type training (3;4). Gibala et al (4) found similar molecular and cellular adaptations in skeletal muscle following 6 sessions of SIT or endurance training (ET) performed over 2 weeks despite the fact that the total training time commitment and exercise volume were significantly lower in SIT groups.

In a more recent study (5), active but untrained subjects performed a constant-load cycling challenge (1 h at 65% of $\dot{V}O_2$max) before and after 6 weeks of SIT or ET. The SIT group trained 3 d/week and each session consisted of four to six repeats of a 30 s 'all out' Wingate Test (mean power output~500W) with 4.5 min recovery between repeats, 3 days per week. The ET group trained 5 d/week and each session consisted of 40 -60 min of continuous cycling at a workload that elicited 65% $\dot{V}$O2max (mean power output 150W). Despite the large time commitment differences, both protocols induced similar increases ($p<0.05$) in mitochondrial markers for skeletal muscle CHO (pyruvate dehydrogenase E1α protein content) and lipid oxidation (3-hydroxyacyl CoA dehydrogenase activity) and protein content of peroxisome proliferator-activated receptor-γ coactivator-1α. Glycogen and phosphocreatine utilization during exercise were reduced after training, and calculated rates of whole-body CHO and lipid oxidation were decreased and increased, respectively, with no differences between groups (all main effects, $P < 0.05$). Given the markedly lower training

volume in the SIT group, these data suggest that high-intensity interval training is a time-efficient strategy to increase skeletal muscle oxidative capacity and induce specific metabolic adaptations during exercise that are comparable to traditional ET. The majority of training studies (4-7) have used relatively untrained individuals and involved cycling as the mode of exercise.

1. Keane S, Reilly T (1993) Analysis of work rates in Gaelic football. Australian Journal of Sports Science 100-102
2. Gollnick PD AR (1973) Effect of training on enzyme activity and fiber type composition of human skeletal muscle. J. Appl.Physiol. 107-111
3. Henriksson J, Reitman JS (1976) Qualitative measures of enzyme activities in type I and type II muscle fibers of man after training. Acta Physiologica Scandinavica 97: 392-397
4. Gibala MJ, Little PJ (2006) Short-term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance. Journal of Physiology 901-911
5. Burgomaster KA, Howarth KR, Gibala MJ (2008) Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. Journal of Physiology 586: 151-160
6. Burgomaster KA, Heigenhauser G J F, Gibala MJ (2006) Effect of short-term sprint interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance. J Appl.Physiol. 2041-2047
7. Burgomaster KA, Hughes SC, Heigenhauser G J F, Gibala MJ (2005) Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. J Appl.Physiol. 1985-1990

2.3 PROPOSED METHOD

Study Overview

The study will take place in the School of Health and Human Performance at DCU and the DCU Sports Grounds. Subjects will undertake 6 weeks (3d/week) of endurance training (ET) or high intensity interval training (HIT). Subjects will visit DCU on 3 separate occasions (1 screening and 2 study visits) before the study and on 2 separate occasions at the end of the study. They will have a muscle biopsy and blood sample taken and will undergo a number of tests to measure body composition, speed, power, agility, lactate threshold, aerobic capacity, anaerobic capacity, and endurance performance. Heart rate will be recorded during each training session and blood lactate levels will be measured before and immediately after the third weekly training session. Each visit will be separated by at least 24 h.

Screening Visit

The screening visit will last approximately 1 h. Subjects will undergo a brief medical examination and perform a Bangsbo Yo Yo Intermittent Recovery test.

Study Visits

Visit 1 - The visit will last approximately 2 h and will be used to measure body composition, muscle power, speed, agility, lactate threshold and maximal aerobic capacity ($\dot{V}O_2max$).

Visit 2 – A blood and a muscle biopsy sample will be taken after which the subject will undertake a 30 sec Wingate test.

Endurance Training Program

Subjects will run on a treadmill at 70-80% $\dot{V}O_2$max. Subjects will run for 30 min during week 1, and the duration will be gradually increased to 40 min by the end of week 2 and remain at 40 min for the remaining training sessions.

Sprint-Interval Training Protocol

Subjects will sprint 100 m followed by a 50 metre recovery run. The sprint and recovery run must be completed in 40 sec. This will be repeated 3 more times followed by a 3 min recovery period (1 set). Subjects will complete 3 sets during the first training session and the number of sets will be increased to 5 during the training study.

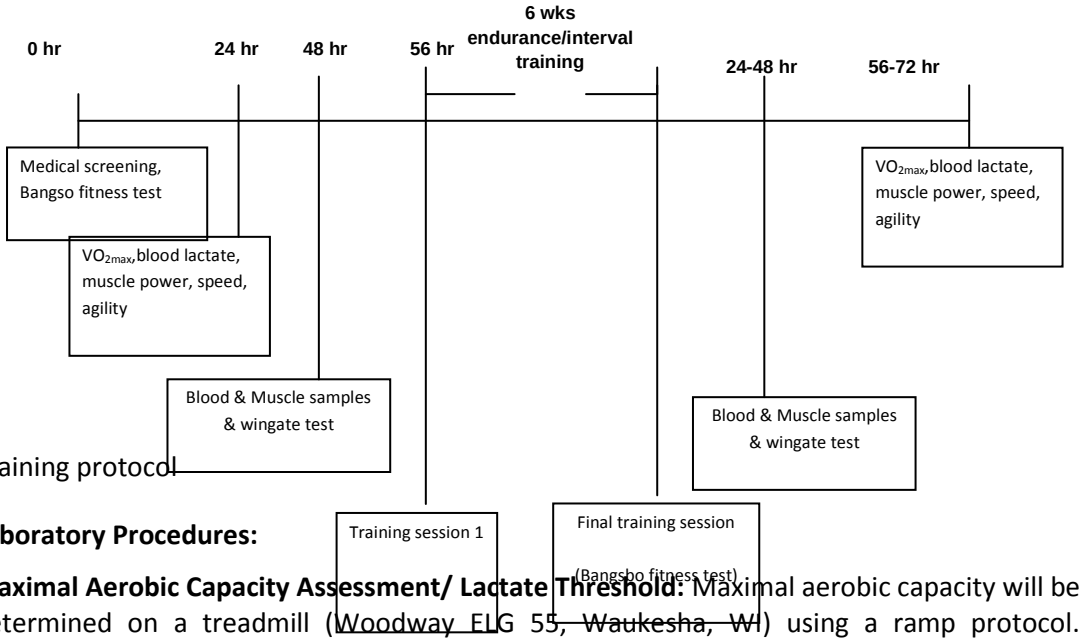

Figure : Training protocol

Laboratory Procedures:

Maximal Aerobic Capacity Assessment/ Lactate Threshold: Maximal aerobic capacity will be determined on a treadmill (Woodway ELG 55, Waukesha, WI) using a ramp protocol. Subjects will warm-up at 8 km/h for 3 min at 1% gradient. Following the warm-up, the speed will be increased 1 km/h every 3 min. At baseline and at the end of each 3 min stage a blood sample will be taken to determine blood lactate concentration. When lactate concentrations reach 4 mmol the speed will remain constant and the gradient will be increased by 1% every 30 sec until the subject reaches volitional exhaustion. The test will be deemed to be maximal if it satisfies at least 3 of the following criteria; levelling of oxygen consumption, volitional exhaustion, RER > 1.1 and heart rate within ± 10 beats of the age predicted max. HR will be recorded continuously, will be assessed each minute.

Respiratory Metabolic Measures: Expired oxygen, carbon dioxide, ventilatory volume and respiratory exchange ratios (RER) will be determined using a Sensormedics Vmax 229 metabolic system (SensorMedics Corp., Yorba Linda CA). Prior to testing, the gas analysers will be calibrated with standard gases of known concentration.

Percent Body Fat: Lange skinfold calliper (Cambridge Scientific Industries, MD) will be used to measure double thickness subcutaneous adipose tissue on the right side of the body. The following anatomical sites will be used: suprailiac, triceps and thigh. A minimum of 2 measurements will be taken at each site. If the measurements vary by more than 1 mm a third measurement will be taken.

Blood Sampling at Rest: A standard venous puncture will be used to collect blood samples at rest before and after the training study. A total volume of 30 ml will be taken.

Blood Sampling During Exercise: Blood samples (5-10 µl) will be taken from the earlobe using capillary tubes. The earlobe will be sterilized with a sterile wipe and then pricked with a lancet (AccuCheck Softclix Pro Lancet, Accu Check, Australia) to promote blood flow.

Lactate Analysis: Whole blood lactate concentration will be measured using a YSI 1500 Sport Lactate Analyzer (YSI UK limited).

Standing Jump for Distance: The subject will jump in a horizontal direction for maximal distance.

Counter Movement Jump (CMJ): The CMJ will be performed on a force platform. Subjects will place their hands on their hips, flex their lower limb joints and then jump vertically as high as possible. The best of 3 trials will be recorded.

Speed: Subjects will sprint 20 metres. Electronic timing gates will be positioned at 5 metres intervals. Each subject will perform 3 trials and the best score will be recorded.

Agility: Subjects will complete a predetermined course in the fastest possible time. The total time will be measured using electronic timing gates. Each subject will perform 3 trials and the best score will be recorded.

Bangsbo Yo Yo Intermittent Recovery test: The Yo-Yo IR level 1 consists of repeated pairs of 20-m runs at a progressively increasing speeds controlled by audio bleeps from a tape recorder. Between each running bout the participants will have a 10-sec rest period consisting of 2x5 m jogs. The test will be terminated if a subject withdraws voluntarily, or is no longer complying to test regulation i.e., when subject does not reach target line on two consecutive occasions.

Wingate Tests: Subjects will undertake a 5 min submaximal warm-up against a light resistance (2.0% body mass) using a self-selected cadence. During the warm-up they will perform 2 separate 5-s sprints against a fixed resistance (4.0% body mass). A 3 min rest period will follow the warm-up. During the first 10 s of the Wingate test the subjects will cycle at approx. 60 rpm against zero resistance. Following a 5-s countdown a resistance equal to 8.5% of the subjects body mass will be applied and the subject will then exercise maximally for 30-sec. Each subject will perform 3 Wingate tests each separated by a 1-min recovery period. Peak power, mean power and total work will be measured. After completion of the third trial, subjects continued to cycle against a light load for 2-3 mins to assist recovery. Peak power, mean power and the total work were measured.

Muscle Biopsy: Rationale for muscle biopsy samples

Skeletal muscle biopsies are necessary before and after the training intervention to determine the molecular and cellular adaptations induced by the training intervention in skeletal muscle.

1. *Little JP. A practical model of low-volume high-intensity interval training induces mitochondrial biogenesis in human skeletal muscle: potential mechanism. J Physiol 588.6: 1011-1022, 2010*
2. *Burgomaster KA. Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. J Physiol 586: 151-160, 2008*
3. *Burgomaster KA. Effect of short-term sprint interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance. J Appl Physiol 100: 2041-2047, 2006*

Statistical Analysis:

A group (Trained or Untrained) x condition (ET or SIT) x time repeated measures ANOVA will be used to compare the mean differences within and between group. SPSS for Windows statistical software will be used to perform the statistical analysis. Statistical significance will be accepted at the $P < 0.05$ level of confidence

2.4 PARTICIPANT PROFILE

Inclusion criteria: Apparently healthy men, currently playing at junior club level or higher level, and between the ages of 18 – 35 years.

Fitness classification will be based on performance in the Bangsbo Yo-Yo Intermittent Recovery test. Subjects who achieve a level ≤ 16.8 will be classified as untrained. Subjects who achieve a level **≥ 16.8** will be classified as trained

Exclusion criteria: Volunteers will be excluded if they smoke or have any other medical conditions that contraindicate exercise participation.

2.5 MEANS BY WHICH PARTICIPANTS ARE TO BE RECRUITED

A recruitment advertisement will be emailed to members of the Dublin City University Gaelic games club and all Dublin city Gaelic games clubs. Permission will be sought from each club prior to posting the advertisement. The aim of the study, the rationale for the study, the tests involved, the time commitment and the potential benefits will be explained to the players. Players will be provided with an opportunity to ask questions. If they wish to participate in the study they will have to provide a written informed consent, which will be witnessed on their visit to the School of Health and Human Performance.

2.6 PLEASE EXPLAIN WHEN, HOW, WHERE, AND TO WHOM RESULTS WILL BE DISSEMINATED, INCLUDING WHETHER PARTICIPANTS WILL BE PROVIDED WITH ANY INFORMATION AS TO THE FINDINGS OR OUTCOMES OF THE PROJECT*?*

The study findings will be presented at scientific meetings and published in scientific journals. Subjects will be provided with a report, which will summarise the relevant results from their participation in the research project.

2.7 OTHER APPROVALS REQUIRED *Has permission to gain access to another location, organisation etc. been obtained? Copies of letters of approval to be provided when available.*

☐ YES ☐ NO ☒ NOT APPLICABLE

2.8 HAS A SIMILAR PROPOSAL BEEN PREVIOUSLY APPROVED BY THE REC?

☐ YES ☒ NO

(If YES, please state both the REC Application Number and Project Title)

3. RISK AND RISK MANAGEMENT

3.1 ARE THE RISKS TO SUBJECTS AND/OR RESEARCHERS ASSOCIATED WITH YOUR PROJECT GREATER THAN THOSE ENCOUNTERED IN EVERYDAY LIFE?

☒ YES ☐ NO *If YES, this proposal will be subject to full REC review*
If NO, this proposal may be processed by expedited administrative review

3.2 WHAT DOES THE RESEARCH INVOLVE:

	YES	NO
• Use of a questionnaire? (attach copy)?	☐	☒
• Interviews (attach interview questions)?	☐	☒
• Observation of participants without their knowledge?	☐	☒
• Participant observation (provide details in section 2)?	☐	☒
• Audio- or video-taping interviewees or events?	☐	☒
• Access to personal and/or confidential data (including student, patient or client data) without the participant's specific consent?	☐	☒
• administration of any stimuli, tasks, investigations or procedures which may be experienced by participants as physically or mentally painful, stressful or unpleasant during or after the research process?	☒	☐
• Performance of any acts which might diminish the self-esteem of participants or cause them to experience embarrassment, regret or depression?	☐	☒
• Investigation of participants involved in illegal activities?	☐	☒
• Procedures that involve deception of participants?	☐	☒
• Administration of any substance or agent?	☐	☒
• Use of non-treatment of placebo control conditions?	☐	☒
• Collection of body tissues or fluid samples?	☒	☐
• Collection and/or testing of DNA samples?	☐	☒
• Participation in a clinical trial?	☐	☒
• Administration of ionising radiation to participants?	☐	☒

3.3 POTENTIAL RISKS TO PARTICIPANTS AND RISK MANAGEMENT PROCEDURES *(see Guidelines)*

The nature and risks involved in the study will be explained prior to starting the study, and a contact number will be provided.

Subjects may experience some muscle soreness in their legs or nausea following the maximal exercise test. Exercise testing carries with it a very small risk of abnormal heart rhythms, heart attack, or death in less than one in 30,000 patients. The pre-test likelihood of these risks in asymptomatic men < 55 years of age is very low. There may be discomfort during the muscle biopsy with some pain and delayed soreness afterward. There is a risk of bleeding, bruising, infection and scaring of the skin. Temporary numbness of the skin near the biopsy site may occur. There may be discomfort when taking blood and the development of a small bruise at the site of puncture.

High intensity may increase the risk for muscle strains and tears. A 5 min warm-up will precede each training session to help reduce the risk of injury.

3.4 ARE THERE LIKELY TO BE ANY BENEFITS (DIRECT OR INDIRECT) TO PARTICIPANTS FROM THIS RESEARCH?

☒ YES ☐ NO The study will provide information than can be used to develop training programs for Gaelic football.

3.5 ARE THERE ANY SPECIFIC RISKS TO RESEARCHERS? *(E.g. risk of infection or where research is undertaken at an off-campus location)*

☒ YES ☐ NO There is a small risk of infection from needle and blood samples. Standard safety procedures will be strictly adhered to.

3.6 ADVERSE/UNEXPECTED OUTCOMES

The School of Health and Human Performance has the facilities to deal with all aspects of this study and an emergency plan is in place for adverse events. All minor injuries will be addressed by an individual trained in first aid (either a member of the research team or the staff). The laboratory is equipped with an emergency crash cart and defibrillator. An individual trained in first aid (or Advanced Cardiac Life Support) will be present during each test. In the unlikely event of a serious adverse outcome, the subject will be brought to the VHI clinic on campus.

3.7 MONITORING

Weekly meetings will take place between Prof. N. Moyna (principal investigator) and the other researchers. These meetings will provide opportunities to access progress, give feedback, and monitor development of the research. The School of Health and Human Performance has a detailed list of Standard Operating Procedures for each of the protocols in this study. All researchers will be familiar with the procedures and the Safety Statement before beginning data collection.

3.8 SUPPORT FOR PARTICIPANTS

It is anticipated that no additional support will be required.

3.9 DO YOU PROPOSE TO OFFER PAYMENTS OR INCENTIVES TO PARTICIPANTS?

☐ YES ☒ NO *(If YES, please provide further details.)*

4. INVESTIGATORS' QUALIFICATIONS, EXPERIENCE AND SKILLS *(Approx. 200 words – see Guidelines)*

Prof. Moyna is an exercise physiologist and has extensive experience with exercise testing

Dr. Noel McCaffrey and Dr. Davide Susta are physicians with extensive experience in the muscle biopsy technique

Crionna Tobin is a PhD student at the School of Health and Human Performance. She has a Bsc, a Higher Diploma in Human Nutrition and a Higher Diploma in Sports Nutrition.

Mr. David Kelly and Cathal Cregg are postgraduate students and have extensive experience in laboratory and field based exercise testing.

5. CONFIDENTIALITY/ANONYMITY

5.1 WILL THE IDENTITY OF THE PARTICIPANTS BE PROTECTED?

☒ YES ☐ NO *(If NO, please explain)*

IF YOU ANSWERED YES TO 5.1, PLEASE ANSWER THE FOLLOWING QUESTIONS:

5.2 HOW WILL THE ANONYMITY OF THE PARTICIPANTS BE RESPECTED?

Confidentiality is an important issue during data collection. Participant's identity, or other personal information, will not be revealed or published. Subjects will be assigned an ID number under which all personal information will be stored in a secure file and saved in password protected file in a computer at DCU. The investigators alone will have access to the data.

5.3 LEGAL LIMITATIONS TO DATA CONFIDENTIALITY: *(Have you included appropriate information in the plain language statement and consent form? See Guidelines)*

☒ YES ☐ NO *(If NO, please advise how participants will be advised.)*

The following statement should be included in the plain language statement.
'Confidentiality of information provided can only be protected within the limitations of the law. It is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professions.

6 DATA/SAMPLE STORAGE, SECURITY AND DISPOSAL *(see Guidelines)*

6.1 HOW WILL THE DATA/SAMPLES BE STORED? *(The REC recommends that all data be stored on campus)*

Stored at DCU ☒
Stored at another site ☐ **(***Please explain where and for what purpose)*

6.2 WHO WILL HAVE ACCESS TO DATA/SAMPLES?

Access by named researchers only ☒
Access by people other than named researcher(s) ☐ **(***Please explain who and for what purpose)*
Other *:* ☐ **(***Please explain)*

6.3 IF DATA/SAMPLES ARE TO BE DISPOSED OF, PLEASE EXPLAIN <u>HOW</u>, <u>WHEN</u> AND <u>BY WHOM</u> THIS WILL BE DONE?

The principal investigator will be responsible for security of the collected data. The data will be kept in locked facilities in the department through which the project is being conducted. Access to the data will only be attainable by the main researchers. Data will be kept for a minimum of five years from the date of publication of the research. Aside from the main

researchers, no others will have access to the raw data. Data will be shredded after five years and Prof. Moyna will carry this out.

7. FUNDING

7.1 HOW IS THIS WORK BEING FUNDED?

The Gaelic Athletic Association

7.2 PROJECT GRANT NUMBER (If relevant and/or known)

7.3 DOES THE PROJECT REQUIRE APPROVAL BEFORE CONSIDERATION FOR FUNDING BY A GRANTING BODY?

☐ YES ☒ NO

7.4 HOW WILL PARTICIPANTS BE INFORMED OF THE SOURCE OF THE FUNDING?

In the plain language statement

7.5 **DO ANY OF THE RESEARCHERS, SUPERVISORS OR FUNDERS OF THIS PROJECT HAVE A PERSONAL, FINANCIAL OR COMMERCIAL INTEREST IN ITS OUTCOME THAT MIGHT COMPROMISE THE INDEPENDENCE AND INTEGRITY OF THE RESEARCH, OR BIAS THE CONDUCT OR RESULTS OF THE RESEARCH, OR UNDULY DELAY OR OTHERWISE AFFECT THEIR PUBLICATION?**

NO

8. PLAIN LANGUAGE STATEMENT

Plain Language Statement

Dublin City University

Project Title: Muscle adaptations in response to low volume high intensity interval training and endurance training in Gaelic games

The Research Study will take place in the School for Human Health and Human Performance DCU and the DCU Sports Grounds

The research study is being funded by the Gaelic Athletic Association.

The principal investigator is: Prof. Niall M. Moyna, (Tel: 7008802 Fax 7008888) EMAIL niall.moyna@dcu.ie

1. A good level of endurance is important for Gaelic football players. Many players spend considerable time running long distances to improve their endurance. Research studies have shown that training involving short sprints with short recovery periods (sprint interval training) can also improve endurance. The amount of time required to improve endurance is considerable less when sprint interval training is undertaken compared to distance running. No studies have compared the effect of endurance training and sprint interval training on endurance performance in Gaelic football players. The purpose of this study is to compare the effect of a 6 week endurance training and sprint interval training program on endurance performance in Gaelic football players.

2. You will make 3 visits to the Human Performance Laboratory in DCU before and 2 visits after taking part in the training program. The first visit before the study will last approximately 1 hour and will involve you undergoing a brief medical examination and performing an endurance exercise test. The second visit will be 2 hours in duration and will be used to measure body fat, muscle power, speed, agility, lactate threshold, and your aerobic fitness. During the third visit you will have a blood and a muscle biopsy sample taken and you will undertake a test on stationary bike (Wingate test) to measuring your power output during exercise. During the final training session you will repeat the same endurance test that you undertook before the study. You will repeat the elements of the previous second and third visits in the human performance lab in DCU 24-48 hrs after the last training session. **During the first of the post-training visits to the human performance lab in DCU you will have a blood and a muscle biopsy sample taken. You will not be allowed to play in any team sport or participate in any other type of exercise program during this 6 week period.**

3. **You will be assigned, by chance, to one of two groups. One group will take part in sprint-interval training and the other group will take part in endurance training. Each group will train 3 times per week for 6 weeks. Subjects randomised to the endurance training group will run on a treadmill at 70-80% of their maximal fitness level. Subjects will run for 30 min during week 1, and the duration will be gradually increased to 40 min by the end of week 2 and remain at 40 min for the remaining training sessions. Each training session will be preceded by a 5 minute warm-up. Subjects randomised to the sprint-interval training will sprint 100 m followed by a 50 metre recovery run. The sprint and recovery run must be completed in 40 sec. This will be repeated 3 more times followed by a 3 min recovery period (1 set). Subjects will complete 3 sets during the first training session and**

the number of sets will be increased to 5 during the training study. Training sessions will be carried out on the sprint track in DCU or in the DCU gym depending on which training program you are undertaking. Each training session will be monitored to ensure compliance.

4. You will receive a report summarizing the results from your tests undertaken during the study. No other benefits have been promised.

5. Your identity and other personal information will not be revealed, published or used in further studies. You will be assigned an ID number under which all personal information will be stored in a secure file and saved in a password protected file in a computer at DCU. The principal investigator, and collaborators listed on this ethics application will have access to the data. You need to be aware that confidentiality of information provided can only be protected within the limitations of the law. It is possible for data to be subject to subpoena, freedom of information claim or mandated reporting by some professions.

6. The original documentation will be stored for a maximum of 5 years. Thereafter the documentation will be shredded.

7. Your participation in this research project is voluntary and you may withdraw your consent at any time.

If participants have concerns about this study and wish to contact an independent person, please contact:

The Secretary, Dublin City University Research Ethics Committee, c/o Office of the Vice-President for Research, Dublin City University, Dublin 9. Tel 01-7008000

9. INFORMED CONSENT FORM

INFORMED CONSENT

Title: Muscle adaptations in response to low volume high intensity interval training and endurance training in Gaelic games

Principal investigator: Prof Niall M. Moyna

Other investigators: Ms Crionna Tobin, Mr Cathal Cregg, Mr David Kelly, Dr. Noel McCaffrey, Dr. Davide Susta

Purpose: The purpose of this study is to compare the effect of a 6 week endurance training and sprint interval training program on endurance performance in Gaelic football players.

Participant Requirements

1. I will have the purpose of the study, each of the steps involved and the risks of participating in the study explained to me. I will have the opportunity to ask any questions and if I am happy with the answers I will provide written informed consent for participation in the research project. I will then complete a medical history form, which will ask questions about my general health, personal and family health history, smoking, exercise, and dietary habits. I will talk with a medical doctor about the information I have provided and I understand, based on the information provided, the medical doctor may exclude me from participating in the research project. If I agree to participate in the study I will make 3 visits to the Human Performance Laboratory in DCU before and 2 visits after taking part in the training program.
2. For the first visit, I will arrive in the morning to the Human Performance Laboratory in DCU following my normal breakfast. I will undergo a brief medical screening to evaluate my current physical condition. I will take part in an endurance fitness test to measure my endurance capacity. This will involve taking part in a repeated pair of 20 m runs at progressively increasing speeds until I fatigue.
3. On my second visit to the Human Performance Laboratory my height and weight will be taken and my percentage body fat will be measured using skin calipers. I will then undergo a series of tests to measure my speed, agility and muscle power. Finally, I will undergo an exercise test on a treadmill to measure my aerobic fitness and lactate threshold. To assess my fitness I will have a mouthpiece similar to a snorkel in my mouth to measure the amount of air I breathe in and out. To assess my lactate threshold I will have my ear pricked to collect a small blood sample
4. During the third visit I will have a blood and a muscle biopsy sample taken and I will undertake a test on a stationary bike (Wingate test) to measure how good I am at performing high intensity exercise. The muscle biopsy sample will involve taking a small piece of muscle, about the size of a pea taken from my thigh with a special biopsy needle. A small area of the leg will be injected with a local anesthetic, then a small incision will be made in the skin and a needle inserted briefly into the muscle. The incision will be closed with sterile strip bandaids, and my leg will be wrapped snugly with an elastic bandage to maintain pressure. Before I leave I will be given supplies to change the dressing around the biopsy sites.
5. After the third visit to the laboratory I will be assigned, by chance, to one of two groups. I will take part in sprint-interval training or endurance training 3 times per week for 6 weeks. At the end of the third weekly training session I will have my ear pricked to collect a small

blood sample to measure my blood lactate levels. This test will assess how well I am responding to each training session.

6. During the last training session I will repeat the same endurance test that I undertook before the study. I will repeat the elements of the previous second and third visits in the Human Performance Laboratory in DCU 24-48 hrs after the last training session.
7. I will not participate in any other type of exercise during this 6 week period.

Sometimes there are side effects from performing exercise tests. These side effects are often called risks, and for this project, the risks are:

1. Exercise testing carries with it a very small risk of exercise induced asthma, abnormal heart rhythms, heart attack, or death in less than one in 30,000 patients. The risk of sudden death during exercise for healthy men is 1:15000-18000. Because I will be asked to give a maximum effort, I may experience some muscle soreness in my arms and legs or nausea following the maximal exercise test. It should be noted that if the experimental protocol is adhered to, the likelihood of these risks occurring is minimal.
2. I understand that the insertion and placement of a cannula (to take blood samples) should be minimally painful but a slight ache may be felt and a small bruise may appear on my arm. There is also a small risk of infection, but by using the appropriate techniques this risk is minimal.
3. I understand that there may be discomfort during the muscle biopsy with some pain and delayed soreness afterward. There is a risk of bleeding, bruising, infection and scaring of the skin. After the biopsy, my leg may feel stiff and sore. Temporary numbness of the skin near the biopsy may also occur.
4. High intensity may increase the risk for muscle strains and tears. A 5 min warm-up will precede each training session to help reduce the risk of injury.

There may be benefits from my participation in this study. These are:

1. I will receive a copy of my personal results, body fat and fitness measurements
2. I understand that no other benefits have been promised me.

Participant – please complete the following (Circle Yes or No for each question)

I have read the Plain Language Statement	Yes/No
I understand the information provided	Yes/No
I have had an opportunity to ask questions and discuss this study	Yes/No
I have received satisfactory answers to all my questions	Yes/No

<u>My confidentiality will be guarded:</u>

Dublin City University will protect all the information about me, and my part in this study, within the limitations of the law. My identity or personal information will not be revealed or published. All records associated with my participation in the study will be subject to the usual confidentiality standards applicable to medical records. In addition, the study findings may be presented at scientific meetings and published in a scientific journal and/or as part of a postgraduate thesis, but my identity will not be divulged and only presented as part of a group.

If I have questions about the research project, I am free to call Prof Niall Moyna at 01-7008802.

Taking part in this study is my decision.

I understand that my participation in this study is voluntary and that I may withdraw my consent at any time by notifying any of the investigators. I may also request that my data and samples be removed from the database or storage and destroyed. My withdrawal from this study, or my refusal to participate, will in no way affect my relationship with Dublin City University or my entitlements as a student or staff member. I understand that my participation in this research may be terminated by the investigator without regard to my consent if I am unable or unwilling to comply with the guidelines and procedures explained to me.

Signature:

I have read and understood the information in this form. My questions and concerns have been answered by the researchers, and I have a copy of this consent form. Therefore, I consent to take part in this research project

Participants Signature: _____

Name in Block Capitals: _____

Witness: _____

Date: _____

Email to participants:

The school of Health and Human Performance is conducting a study to compare the effect of a 6 week endurance training and sprint interval training program on speed, agility, power and endurance performance in Gaelic football players. You will make 3 visits to the Human Performance Laboratory in DCU before and 2 visits after taking part in the training program. The first visit before the study will last approximately 1 hour and will involve you undergoing a brief medical examination and performing an endurance exercise test. The second visit will be 2 h in duration and will be used to measure body fat, muscle power, speed, agility, lactate threshold and your aerobic fitness. During the third visit you will have a blood and a muscle biopsy sample taken and you will undertake a test on a stationary bike (Wingate test) to measure your power output during exercise. You will then be assigned, by chance, to one of two groups. One group will take part in sprint-interval training and the other group will take part in endurance training 3 times per week for 6 weeks. During the last training session you will take part in an endurance test. You will repeat the elements of the previous second and third visits in the Human Performance Laboratory in DCU 24-48 hrs after the last training session. We are looking for 40 healthy men, currently playing Gaelic football at any level, and between the ages of 18 – 35 years.

If you would like to hear more about this study or would consider participating, please contact one of the following;

Crionna Tobin
Email: Crionna.tobin9@mail.dcu.ie
Mobile number: 086-0705130

David Kelly
Email: david.kelly59@mail.dcu.ie
Mobile number: 085-1618207

Cathal Cregg
Email: cathal.cregg2@mail.dcu.ie
Mobile number: 087- 7633021

Thank you,

Niall M. Moyna, PhD

Standard template for ethical justification for blood sampling associated with human studies conducted within DCU.

Completion instructions:

This document is intended to prompt responses to a number of standard questions which generally need to be answered to justify the sampling of blood associated with human studies.

The document is not meant to be an exhaustive exploration of the justification for such sampling and in specific situations. Additional information may be required/ requested.

Answers are expected to be brief but should also be informative. See a sample completed form at the end.

Queries should be directed to the Secretary of the Research Ethics Committee in the OVPR office.

1) **Briefly explain why blood sampling is required**

To monitor circulating levels of glucose, lactate, free fatty acids and insulin, this will be used to determine adaptations in the subjects following the research intervention

2) **Outline the analyses, components or general applications to be investigated in subject blood (now and any future studies)**

Blood lactate will be determined using a YSI 1500 Sport Lactate Analyzer (YSI UK limited). Glucose will be analysed using a YSI 2300 Analyzer (YSI UK limited). Free fatty acids and insulin will be investigated using an automated clinical chemistry analyzer, Randox Daytona (Randox UK limited)

3) **Are any alternatives available to substitute the venous sampling of blood? yes/no.**

No

4) **Will sampling require cannulation or direct vein puncture?**

Direct vein puncture and ear prick with lancet

5) **Outline the minimum volume of original subject blood (i.e. not serum or plasma) required to measure the required components.**

4.0 ml for circulating levels of glucose, free fatty acids and insulin.

6) **Are steps being taken in the protocol to minimise the volume of blood samples being taken? Yes**

7)

Yes. We have taken the minimum volume of blood that will allow us to examine circulating levels of glucose, lactate, free fatty acids and insulin.

Yes. We have taken the minimum number of blood samples that will allow us to examine circulating levels of glucose, lactate, free fatty acids and insulin.

8) **Anticipated sampling methodology**

Volume of blood to be taken per sample	4.0 ml for glucose, insulin and free fatty acids 100µl for lactate
Maximum number of samples to be taken per "sitting"	6 for lactate 6 for glucose, insulin and free fatty acids
Maximum number of samples taken per day	Screening Visit- 0 samples Visit 1 – 6 samples Visit 2 – 6 samples During training – 2 samples Visit 3 (post training program) – 6 samples Visit 4 (post training program) – 6 samples
Maximum number of samples to be taken over the course of the full study (if long duration study indicate the amount taken in an active 1 month period)	12 blood samples and 14 lactate samples
Maximum anticipate number of vein puncture episodes	2
Total volume of blood that will be taken from subject.	50 ml

9) I certify that:-

- all persons sampling blood in this study are certified to do so through the school/unit where this work is being conducted
- that all those manipulating the resultant samples are fully trained in the safe practice of handling blood
- All persons handling this blood have received appropriate information according to current vaccination policy.

Signature of Study PI Niall Mayna Date:

An original signed copy must accompany electronic submissions. Alternatively, a PDF or other scanned version with a signature may be submitted

APPENDIX II – PAR-Q Questionnaire

PAR – Q & YOU QUESTIONAIRE

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO

YES	NO	No.	Question
		1	Has your doctor every said that you have a heart condition and that you should only do physical activity recommended by a doctor?
		2	Do you feel pain in your chest when you do physical activity?
		3	In the past month, have you had chest pain when you were not doing physical activity?
		4	Do you loose your balance because of dizziness or do you ever lose consciousness?
		5	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
		6	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition/.
		7	Do you no of any other reason why you should not do physical activity?

If you answered YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES

- You may be able to do any activity you want – as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kind of activities you wish to participate in and follow his/her advice
- Find out which community programs are safe and helpful for you.

If you answered NO to all questions.

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- Start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- Take part in a fitness appraisal- this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

Delay becoming much more active:

- If you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- If you are or many be pregnant – talk to your doctor before you start becoming more active

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

NAME_____.

SIGNATURE_____ DATE_____.

SIGNATURE OF PARENT_____. WITNESS_____.

Or Guardian (for participants under the age of majority)

APPENDIX III – Data Collection

Data Collection Sheet

Name: _____

Address: _____

_____

_____

Tel no.: _____

Date of Birth: _____/_____/_____

Medical Conditions:

Cardiovascular Disease □

Pulmonary Disease □

Diabetes □

Asthma □

Other Medical conditions:

_____

_____

Height: _____ cm

Weight: _____kg

Power

Contermovement Jump (cm) _____ _____ _____

Vertical Jump (cm) _____ _____ _____

Speed

5m split time (secs) _____ _____ _____

20m split time (secs) _____ _____ _____

RE Data Collection Sheet

RHR: _____ bpm **BP:** ____/____

Date of Test: ____/____/_____ **Time of Test:** _____

Tester's Name: _____

Stage	Time (mins)	Speed/Slope	RPE-O	HR (bpm)	Lactate mmol/l

Maximal Data:
HR max: _____ bpm
RPE-O max: _____
Absolute $\dot{V}O_2$max: _____ l/min
Relative $\dot{V}O_2$max: _____ ml/kg/min