PHYSIOLOGICAL DEMANDS OF OFFICIATING IN THE GAME OF RUGBY UNION AT THE SENIOR LEVEL

by

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ABSTRACT

The aim of this study was to evaluate the physiological demands of officiating in the code of Rugby Union at an elite level and to propose a relevant programme of fitness testing and training arising from the results obtained. A group of ten RFU National Panel referees were selected as subjects and all were analysed performing match duties as both a referee and a touch-judge during a number of level 1 and 2 league matches. Each subject performed a range of laboratory tests to establish various physiological parameters, which were then compared with the match analysis findings of heart rate and total match distances.

The mean total match distance covered by the referees was 8086 metres (s.d. +/- 799 metres), with a range of 7036 to 9143 metres. Heart rate during the matches averaged 86% (s.d. +/- 3.2 beats/min) of the referees' maximum, with a range of 81 to 90%. This corresponded to a mean heart rate of 157 beats/min (s.d. +/- 7.6 beats/min) with a range of 144 to 167 beats/min. The time spent above the heart rate corresponding to the onset of blood lactate accumulation (OBLA) level of 4 mmol/l, recorded through laboratory testing, averaged 52.0% (s.d. +/- 24.7%) of the total match, with a range of between 10.9 to 84.3%.

The mean total match distance covered by the touch-judges was recorded as 4906 metres (s.d. +/- 666 metres), with a range of 3985 to 6409 metres. 95% of the

total distance covered was found to be within the walking, jogging or running (forwards and backwards) categories of movement. This corresponded to a mean heart rate of 108 beats/min (s.d. +/- 12.5 beats/min) with a range of 88 to 126 beats/min. Very little time was spent with heart rate corresponding to OBLA, an average of 0.1% (s.d. +/- 0.2%) of the total match time, with a range of 0 to 0.5%.

The quantity of work performed during a match by Rugby Union referees and touch-judges was found to be substantially greater than in previous research, suggesting a need to review both fitness testing and training programmes presently accepted. There is also a need to test and develop the metabolic pathways of the anaerobic system of referees at the elite levels of the game. An intermittent field test, specific to the demands of officiating, was devised and tested as a potential replacement for the multi-stage fitness test.

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CHAPTER 1

INTRODUCTION

1.1 Background to the problem

During a meeting of the International Rugby Football Board in August 1995 a decision was made that changed the nature of the game of Rugby Union overnight. The ruling body announced that the code of Rugby Union, amateur for over 100 years, was to become fully professional. Although many observers at that time viewed this measure as an inevitable change due to the semi-professional attitudes that several of the world's governing bodies had been exhibiting for some years, this decision had far reaching consequences for all concerned at the highest level of the game. Many players have now become full-time, highly paid professionals, bound by contracts to club and, in several instances, country. This has enabled them to develop their fitness and skill levels well beyond their previous limits, as they now have a massively increased time allowance for club and personal training, with no vocational distractions inhibiting this.

Sport scientists have also become involved in designing physiological and psychological training programmes to optimize the attributes of the players across many of the professional clubs, leading to an increased rigour in the approach of the athletes.

Outside of the immediate playing structure of the sport, crowds continue to expect improvements in the game if they are to pay increasing amounts of money for what has been, until the advent of professionalism, a relatively cheap spectator sport. The first three seasons of professionalism has seen a marked increase in attendance, particularly for the 'nouveau riche' clubs of the Premier Division.

Satellite television moguls have begun to take an increased interest in the commercial possibilities of the game, with several wealthy businessmen also realizing the potential financial gains to be made from the game. Sponsors and the media have also required the sport to improve as a spectacle and this will place increasing demands on the players - both physically and mentally. Recently several of the financial backers of the professional clubs have begun to question their involvement in the sport and this will probably lead to an even greater commercial push for the development of the game.

However in all of this there remains the question of those men (and women) 'in the middle' - the referees and touch-judges. Their amateur status has begun to alter with the increased revenue being generated by the RFU and, in the season of 1996-97, there came into being the first match fee system for the National League officials. Although this was regarded by many as a nominal sum of money in comparison to that which some of the players were earning, it was nevertheless regarded as the first step to changing the status of the officials within the overall sphere of the game. Since this time a continual review of fees, expenses and contracts has been undertaken and a move towards full-time professionalism of officials is underway, with the first appointments having been made in the 1998/99 season.

This 'semi -professional' standing that the majority of the RFU match officials currently operate under has led to a shifting of attitudes by the players and their pay-masters away from the old amateur, Corinthian-style ethos, with an increased demand for improvements in the officials' overall performance. Davies (1991) pointed out that 'players are learning from other contemporary athletes and are committing themselves to rigorous training regimes' and that 'players are becoming more powerful and are capable of playing the game at a significantly greater intensity than players of twenty years ago.'

Undoubtedly the participants in Rugby Union have, since this statement was made, continued to become even fitter and more skilful and this fact, allied to the likelihood that the sport's administrators are continuing to modify the laws and structure of the game to make it quicker and more 'spectator-friendly', is leading to increased fitness and training demands on the top referees.

1. 2. Current fitness demands on officials

This increased pressure, however, will not come as a surprise to officials, as the last eight years have seen the game become a faster, more competitive sport with the introduction of leagues to add to the existing national cup, divisional and county championships. Spiller (1990) highlighted the issue of referees' fitness by stating that 'referees would be the first to agree that today, more than ever, they owe the players the responsibility of performing at their optimum level of fitness for the entire eighty minutes.' Trotter (1994) adds that 'as players get stronger, fitter, faster then surely so will the need for referees to be able to keep pace grow' and 'the referee must at least be able to keep up with the level of the game being refereed.'

This statement has even more recently been expanded upon by Rutherford (1995) who has stated that 'the need for referees to be up with the speed of the game both mentally and physically is talked about quite freely' and 'as many of the ambitious teams will keep going for the full 80 minutes, so will the ambitious referee.' This has already placed the officials in a situation where they have had to become more conscientious in their approach to the game and thus fitness standards have been raised at all levels. In support of this view, Davies (1991) stated that there is a 'need to instill' in all rugby union officials 'the dedication and discipline required to maximise ...... fitness' and that 'high status games should be identified at the beginning of the season and the mental and physical approach honed accordingly.'

1. 3. Fitness testing - a historical perspective

Since the 1993-94 season the RFU have introduced the concepts of an appointed touch-judge panel with disciplinary powers for national league matches and regular fitness testing for all RFU officials. This system has been modified and adapted on a frequent basis and there are now minimum standards for referees to achieve on the multistage fitness test, a record of a subject's estimated $\dot{V}O_2$ max, if they are to continue to receive RFU appointments. This test involves the participants running back and forth along a twenty metre track, in time to a pre-recorded 'bleep' which increases in pace each minute. The participants attempt to run for as long as possible until it is impossible to keep up with the pace set by the 'bleep'. The test is therefore a incremental test, with procedures not dissimilar to those for determining maximum oxygen uptake.

The initial minimum standard on the multi-stage fitness test of level 10, shuttle 4, was established as a benchmark on the basis of research performed at Loughborough University and formulated in the light of the standards already established by the Football Association for officials in the code of soccer.

There is now, however, increasing pressure to review this standard in the light of changes occurring within the professional game and from the 1998/99 season referees were required to achieve level 11, shuttle 5. The RFU also adopted, for the 1998/99 season, the use of the Cooper 12 minute test. This test was established as an alternative test to the multistage fitness test, with a benchmark of 2900 metres to be covered in the test time. In this test the participants are asked to complete as many laps of a measured course, usually a 400 athletics metre track, as is possible in twelve minutes. The participants can walk, jog or sprint during the test and the result is calculated in terms of metres covered at the end of the test period.

Prior to the establishment of this protocol, touch-judges have been fitness tested for some years now utilising the process of a repeated sprint test as a method of establishing an individual's match fitness. The test involved running a distance of forty metres with two turns and repeating this eight times with a short rest interval in between each repetition. The 'benchmark' for a successful score by the participants was regarded by the RFU as completing each shuttle in a prescribed time.

This use of 'benchmark' minimum standards for referees and touch-judges creates a number of philosophical questions to be debated when examining the focus of the RFU on the rationale for fitness testing and the standards and protocols so far established. The first question is whether the current testing protocols for referees and touch-judges, based on the underpinning criteria of maximum oxygen uptake (the multistage fitness test and the Cooper 12 minute test), is reflective of the demands of the game? Are the tests adopted sufficiently specific to the demands of the code of Rugby Union or should the RFU look to alternative tests, which are more representative of the workload undertaken within the game?

Another philosophical question to be considered is what are the legal and employment implications in a professional game for establishing compulsory fitness targets based on collated research? Would the standards and targets set by the RFU stand up to rigorous examination? Much of the fitness testing being carried out at present on rugby officials owes its justification to the thesis by Spiller (1990) and associated work. Whilst the value of this ground breaking research was inestimable at the time, the nature of the game as outlined above has changed dramatically in the last nine years and there is now the possibility that the data collected then is now outdated and needs careful re-examination.

Also what are the health and safety implications for placing individuals of various ages, backgrounds and physical fitness through a programme involving maximal testing? Finally are the tests beyond reproach when examined from a viewpoint involving the validity, reliability and specificity of the testing programme? These questions will be reflected upon when recommendations for future testing protocols are made in later chapters.

To summarise, the advances in recent years are therefore plain to see and the role of the official, whether referee or touch-judge, will be placed under increasing scrutiny.

1. 4. The aims of the study

It is the aim of this study, therefore, to examine what the present demands of the game are on the physiological processes of the match officials and also to make valued recommendations for the future testing of referees and touch-judges at the top level of the game. The study will look to collect match data on physical workloads undertaken by a group of RFU referees and touch-judges, through movement and heart-rate analysis, and relate the data to results obtained by means of a variety of laboratory assessments so that recommendations can be drawn up for future testing protocols.

It is the belief of the author that due to the shifting demands of the game of rugby union this research should examine the following experimental hypotheses:

Hypothesis 1 - The physiological workload placed upon a referee at the top levels of the game, measured in distance travelled, has increased significantly beyond levels recorded previously.

Hypothesis 2 - The quantity of high intensity work undertaken by a referee at the top levels of the game, measured in total match distance covered at speeds above jogging levels, has increased significantly beyond the levels recorded previously.

Hypothesis 3 - The quantity of high intensity work undertaken by a referee at the top levels of the game, measured in percentage of total match distance covered at speeds above jogging levels, has increased significantly beyond the levels recorded previously.

Hypothesis 4 - Due to there being a significant increase in high intensity work undertaken by a referee (Hypothesis 2), fitness testing procedures should be increased in rigour and diversity.

Hypothesis 5 - There has been a significant increase in the workload of touch-judges and, due to this, the fitness testing protocols of RFU touch judges have a need to be re-evaluated and increased in their rigour.

1. 5. The definition of terms used in the study

The following terms have been used throughout the study and are defined as follows:

Absolute exercise intensity – 'a measure of exercise intensity which is independent of the individual's fitness levels, (e.g. running at 9 m/sec)'

Aerobic metabolism – 'the process by which energy (ATP) is produced, occurring in the mitochondria, which utilizes oxygen'

Aerobic power – 'maximal rate at which an individual can consume oxygen during the performance of exhaustive exercise'

Anaerobic metabolism – the process by which energy (ATP) is produced, occurring in the sarcoplasm, which does not involve oxygen'

Endurance capacity – 'the time limit of a person's ability to withstand fatigue at a set speed.'

Endurance performance –	'the time taken to complete a set task, e.g. time taken on the Cooper 1.5 mile field test.'
Fitness –	'the ability to perform work related tasks (i.e. refereeing) without undue fatigue'
Relative exercise intensity –	'a measure of exercise intensity which is related to the individual's fitness levels, (e.g. running at 110% $\dot{V}O_2$ max)'

CHAPTER 2

REVIEW OF LITERATURE

2. 1. Introduction

Although much of the research in the past twenty years has concentrated on the other codes of football - Association, American and Australian Rules and not specifically upon the game of Rugby Union, a good deal of the published material is still of benefit to this study, as there are a large number of similarities existing between the codes. All of the games mentioned above belong to the invasive, field category of sports and place an intermittent work load on the participants.

The nature of these codes of football involves the major energy systems of the body in varying degrees and phases of physiological work are interspersed with periods of rest or lower levels of work. These spasmodic periods of rest usually occur due to players' infringements, injury or the ball becoming unplayable. Therefore the requirements of the players and officials in these sports can, due to the number of similarities existing between the codes, be examined with a view to comparisons being made to the game of Rugby Union.

When examining which of the three energy systems is prevalent in providing a rugby official with the ATP required for the multitude of different activity phases that the individual undertakes, the 'energy continuum' for various sports activities should be examined. This is due to the fact that a game of rugby involves exercises that are both short-term, high-intensity efforts, that utilize the anaerobic energy systems, such as sprinting into the in-goal area for a goal-line decision and long-term, low intensity efforts, that utilize the aerobic energy system, such as jogging between successive rucks. It is therefore not possible to classify the sport of rugby as either anaerobic or aerobic but to view it in the light of having a blend of all the energy systems.

The energy continuum as described by Davis, Kimmet and Auty (1986) is illustrated in figure 1. This attempts to define various sporting activities as having a certain percentage contribution from the aerobic and anaerobic systems. It would appear from this diagram that the total energy contribution for an official within the game of Rugby Union would be approximately 30-40% aerobic and 60-70% anaerobic, as this is where the other invasive, intermittent-style games of Lacrosse, Field Hockey and Association Football are located on the continuum. It is likely that the activities involved in a game of this nature will call on anaerobic energy sources, for instance through the player performing high-intensity shuttle runs as movements from one phase of the game to another are required. A player covering back in defence and then moving forward to support teammates in attack will require a high rate of energy conversion from ATP/PC and lactic acid energy systems. Likewise these codes will require a supply of energy from the aerobic system, as the player recovers from the high intensity periods of play and moves at walking and jogging paces to fulfill the positional requirements of the player's role.

However this is only realistically a starting point for the analysis of energy production sources for an official in Rugby Union as the continuum suffers from generalization. It does not attempt to break the various codes of football down into positions on the field, as the energy continuum of a goalkeeper in Association Football will be different to that of a midfield player. Likewise in the code of Rugby Union, a prop forward's responsibilites involve scrummage, line-out and rucking/mauling duties, which are different from those of a winger, where little of such work is required. Nor does it examine which areas of the game will require aerobic as opposed to anaerobic supplies of energy. Nevertheless the energy continuum does allow a reference point for the research into movement analysis to be based upon and, as such, has provided the starting point for much of the work into intermittent-style sports.

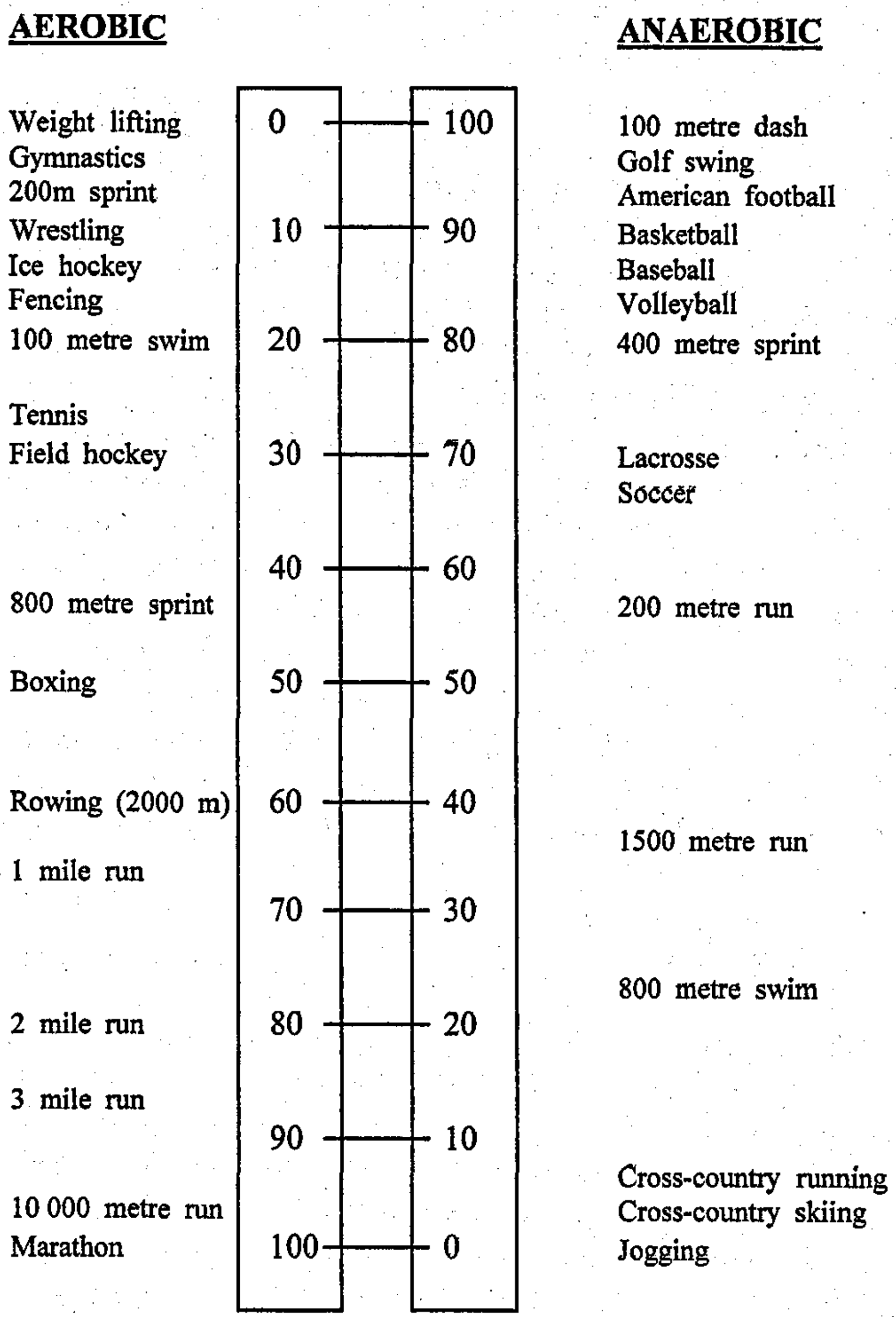


Figure 1 The energy continuum and various sporting activities. (From Davis, Kimmet and Auty, 1986)

2. 2. Fitness demands of intermittent-style invasive games

2. 2. 1. Introduction to current research

Many of the recommendations about the referees' fitness testing and training protocols, made by the Rugby Football Union, are based on the work by Spiller (1990) and the basis of this research should now be examined in the light of the new professional game.

As Rutherford (1995) points out, after drawing conclusions from the research of Spiller (1990), 'the modern game is increasingly faster, with an emphasis on continuity, which creates an even greater demand on referees' fitness levels.'

Since this statement was published the laws of the game have continued to be modified and this fact, in conjunction with the playing directives now agreed between top coaches, players and referees in England on a seasonal basis, has meant that the game has increased even further in pace and intensity. Williams (1996) reinforced this viewpoint by stating that 'the arrival of true professionalism, and any minor law changes that may be made, will only serve to place more emphasis on fitness standards approaching those of track and field athletes.' This highlights the need for a thorough re-examination of the current state of officials' fitness demands in the light of recent developments and the likelihood that the game will continue to change radically in the near future.

When examining the physiological demands of a game such as rugby union it is important to bear in mind that a crucial factor is the relevant exercise intensity at which most of the different activities are performed. When developing fitness training and testing regimes for match officials it is the percentage breakdown of these various exercise intensities which will determine the overall design of such programmes. Also within these programmes consideration must be given for officials' vocations, habitual activities, dietary requirements and the need for prevention of injuries.

It is interesting to note that concepts of fitness testing and measurement for the code of rugby union were being discussed over twenty years ago when Evans (1973) stated that '...stress is being laid upon the physical requirements of the game so that qualities of muscular strength, muscular endurance, speed and stamina ...... are being increasingly more accepted as being basic ingredients for the recipe of good play.' Similarly Reid and Williams (1974) concentrated their work on the premise that 'the most important area of fitness for rugby football is that of the cardio-vascular response to a continual high level of physical output.'

Later research by Docherty et al (1988) reinforced the viewpoint that the stamina aspect of fitness is the key to performance in rugby by stating that, 'it is important to build both aerobic power and aerobic capacity. Aerobic power will facilitate the non-intense running match play activities and enhance the recovery of the phosphagen stores,' and '.... players will benefit by increasing their aerobic capacity.' This view is supplemented by Williams (1996), who stated that 'it is accepted that aerobic power is necessary to recover between intense bouts of exercise' and reinforced by Deutsch et al. (1998) who states that 'the intermittent nature of rugby union suggests that the oxidative (aerobic) and creatine phosphate (anaerobic) pathways are the major contributors to adenosine triphosphate (ATP) regeneration during rugby.' It appears from these statements that Docherty et al (1988) and Williams (1996) defined 'aerobic power' as the speed by which the body can repay oxygen deficit or supply ATP requirements via aerobic metabolism whereas 'aerobic capacity' is the equivalent of maximal oxygen uptake ability.

Certainly much of the research within invasive field sports, which have such intermittent-style work patterns, has pointed to the need for a high maximum aerobic capacity ($\dot{V}O_2$ max) in order that prolonged bouts of work can be carried out by the athlete. It has been found that, in Association Football, the distance covered in a game is highly correlated with the player's $\dot{V}O_2$ max value (Reilly, 1993) and that the number of sprints that a player attempts is also linked to their $\dot{V}O_2$ max (Smaros, 1980).

Allied to this fact is that the upper limit at which continuous exercise can be maintained is also important to invasive field sports' athletes and this 'is influenced by the 'anaerobic threshold' and a high fractional utilization of VO_2 max' (Reilly, 1990). Williams (1996) counters this by stating that 'as yet, scientific observation does not seem to support the idea that the lactic-acid system is stressed significantly for most rugby players.' This is further reinforced by Deutsch et al. (1998) who states that 'the contribution of anaerobic glycolysis to rugby union .... remains unclear.' However the emphasis recently, within intermittent-type sports, is that high intensity work is becoming increasingly more important and the evidence for an increased focus on anaerobic metabolism is examined again later in this chapter.

Certainly there is evidence within Association Football that counters the view of Williams (1996), with Reilly (1996) stating that while 'most activity during a game is at low or submaximal level of exertion ..... players generally have to run with effort (cruise) or sprint every 30 seconds.'

It is also likely that the timing of these exercise periods, probably anaerobic in the main, are crucial to the success of the player and their team. An official within the game of Rugby Union probably also has a similar importance attached to bouts of high intensity activity, as they must ensure that they are in the right position at the right time, to make crucial, borderline decisions that can be highly influential to the result of a game. Spiller (1990) reinforces this by stating that speed is 'a vital asset for a referee in the game of rugby as is speed off the mark. An interception ..... can totally change the direction of play in a split second. The referee must also be able to keep up with a fast breakaway to be able to observe any forward passes.' Williams (1996) also states that 'it is accepted that the short-term energy system, mainly the phosphocreatine system, is repeatedly stressed' within the game of Rugby Union.

2. 2. 2. Research findings on players' movement patterns

The research conducted into intermittent style games has focused largely on the more popular code of Association Football, with a variety of studies utilizing motion analysis to calculate the physical workloads on players. A summary of overall work-rates in the literature is shown in table I (Reilly, 1996). This data indicates that outfield players are covering between 8-12 kilometres during the course of a match and there are on average around '1000 different activities in a game or a break in the level or type of activity once every 6s' (Reilly and Thomas, 1976).

The overall distance covered by outfield players in an average English top division match consists of 24% walking, 36% jogging, 20% cruising, 11% sprinting, 7% moving backwards and 2% moving in possession of the ball.

These figures have also been reported as 'indicative of other major national leagues in Europe and at a top level in Japan.' (Reilly, 1996).

The ratios of low intensity (below cruising pace) work to high intensity work have also been examined and has been reported as being about 2.2:1 in terms of distance covered and about 7:1 in terms of time, 'denoting a predominately aerobic outlay of energy.' (Reilly, 1996).

Table I Mean distance covered per game according to various sources in Association Football (From Reilly, 1996)

Source	n	Distance covered (m)	Method
English	40	4834	Hand notation
Finnish	7	7100	TV cameras (2)
English	40	8680	Tape-recorder
Japanese	2	9845	Trigonometry (2 cameras)
Swedish	10	9800	Hand notation
Japanese	-	9971	Trigonometry
Belgian	7	10245	Cine-film
Danish	14	10800	Video (24 cameras)
Swedish	9	10900	Cine-film
Czech	1	11500	Undisclosed
Australian	20	11527	Videotape
Japanese	50	11529	Trigonometry

Data relating to cardiovascular and blood lactate variables has also been collated in the code of Association Football and this data is presented in summary format in tables II and III. Van Gool et al. (1983) have reported mean figures of 155 beats/min for a centre-back and a full-back, 170 beats/min for a midfield player and 168 and 171 beats/min for two forwards throughout a match. This research team also conducted research on a Belgian university team during a friendly match and reported values of 169 beats/min in the first half and 165 beats/min in the second half. Reilly (1996) states that 'these trends have been confirmed in matches played by English university teams' and 'most estimates are that the exercise intensity during soccer is about 75-80% $\dot{V}O_2$ max'.

Results of lactate analysis during competitive Association Football matches have found values of 4-6 mmol/l, on average, during play, but Ekblom (1986) claimed that 'peak values above 12 mmol/l were frequently measured at the higher levels of soccer play.'

Table II Mean values for heart rate (beats/min) during soccer (From Reilly, 1996)

Series	HR (bpm)	Match-play situation
Seliger (1968a)	160	Model 10 min game
Seliger (1968b)	165	Model 10 min match
Reilly (1986)	157	Training matches
Ogushi et al (1993)	161	Friendly match (90 min)
Ali and Farrally (1991)	169	Friendly match (90 min)
Florida-James and Reilly (1995)	161	Competitive game (90 min)

Table III Mean (+/- s.d.) blood lactate concentrations (mmol/l) during soccer (From Reilly, 1996)

1st half	2nd half	Source
5.1 (+/- 1.6)	3.9 (+/- 1.6)	Rhode and Espersen (1988)
5.6 (+/- 2.0)	4.7 (+/- 2.2)	Gerisch et al (1988)
4.9 (no s.d. recorded)	3.7 (no s.d. recorded)	Bangsbo et al (1991)
4.4 (+/- 1.2)	4.5 (+/- 2.1)	Florida-James and Reilly (1995)

Research into the other codes of football has also examined the movement patterns of the players involved. In Australian Rules players have found to cover, on average, 'over 10 kilometres per game, composed of 27% walking, 53% jogging and the remaining 20% striding or sprinting.' (Douge, 1988). Similar patterns to those in Association Football, with regard to differentiation of workload according to positional roles, have been found. Pyke and Smith (1975) suggested that 'the distance covered by a half-back flanker in a game was about 77% of that of a rover.'

Mean heart rate during competitive matchplay in Australian Rules has been reported by Douge (1988) as '161 beats/min', a value comparable to that found in Association Football. Pyke and Smith (1975) reinforce this finding with figures 'fluctuating between 170 and 185 beats/min most of the time' and an overall mean heart rate of 178 beats/min for the entire match. The rate did not fall below 150 beats/min at any time.

Although numerous studies have been conducted in the related field of Association Football, the data available from the field of Rugby Union remains sparse. Docherty et al (1988) reported that 'players spent 85% of total playing time in low-intensity activity (standing, walking or jogging) and only 15% of playing time in high intensity activity (running, sprinting or static exertion).'

There appeared from this study to be a division of labour within the game as inside backs spent more time sprinting than prop forwards (3% versus 1%) but the forwards spent more time engaged in static exertions (16% versus 3%). Treadwell (1988) also discovered that players spent a large quantity of time (73% for backs, 64% for forwards) engaged in low-intensity activities (rucking/mauling, scrummaging, standing, walking and jogging) although there is an argument for regarding rucking/mauling and scrummaging work as more demanding than 'low-intensity'. Treadwell (1988) appears to give little justification for the categorization of the movement types.

McLean (1992) reported that '63% of high-intensity work periods (running, scrummaging, lineouts, rucking and mauling) were shorter than the ensuing rest.' Many of the work-to-rest ratios were between 1:1 and 1:1.9 with the mean duration of each work period being 19 seconds.

Calculations of total distance covered by players in a match have ranged from 3.8 to 9.6km (Reid and Williams, 1974; Williams, 1976; and Morton 1978). However there have been problems over the use of standardised recording and measuring techniques and the differences in classifications of movement patterns, which has raised questions over the validity of these measurements. More recent research by Deutsch et al. (1998) has attempted to resolve these issues through use of video playback and associated computer analysis. It was found that the players covered between 4240 metres (backs) to 5640 metres (forwards), although the accuracy of these figures is questionable, as the results were obtained by doubling the data from 35 minutes of play, rather than from analysing the entire match.

The major problem with much of the research is that there is an overwhelming concentration on the demands of the game on the players' physiological processes and very little has been specifically tied to the needs of the officials involved in the game. This has created problems when making recommendations for the structure of fitness testing and development of fitness programmes for the officials, as the physical demands of this group are different from those of the players. For example, referees in Rugby Union are not involved in the physical contact aspects of the game, such as tackling and mauling, but this is not to say that muscular strength and muscular endurance are not an integral part of the physical demands of the game and these components should not necessarily be ignored when devising appropriate fitness programmes.

Alongside this is that there are extreme demands placed on the referee's mental capabilities, including concentration, perception and decision-making skills. As Reilly (1996) states, 'These decision-making stresses are superimposed on a relatively high level of physiological stress,' and thus have 'implications for fitness required to officiate at a high level.' The research on referees in various codes of football needs to be analysed for more specific findings related to officials in Rugby Union.

2. 2. 3. Research findings derived from officials within the various codes of football

Much of the research in the field of physiological analysis has focused on the code of Association Football, due in large part to its global popularity and status as the pre-eminent code, and it is worth highlighting the demands on officials in this intermittent style game. Catterall et al. (1993) discovered that referees in the Premier Division of the English League cover approximately 9.5 km during the course of the game. Of this total distance, on average 47% is covered at a jogging pace, 23% walking, 12% sprinting and 18% reverse running. Top-class referees in Japan have had greater total match distances reported, with Asami et al. (1988) finding that foreign referees in international matches and referees in the Japan National Soccer League covered 10.5 km and 11.2 km respectively. These figures closely matched those reported for professional players and exceed those of some positions within the game, e.g. central defenders.

In comparison research on officials in the code of Rugby Union football is relatively limited, with the work by Spiller (1990) providing the major focal point. Spiller (1990) found that 'the average distance covered in an eighty minute game of first class standard for a referee is approximately 4878 metres or 3 miles, but it could be as high as 6074 metres or 4 miles.' The total distances covered by the referees in the research by Spiller (1990) are outlined in table IV. The table has been adapted from the research by Spiller (1990) with the removal of the decimal places, as it was felt that the methods of determining total distance covered by the officials would not have been sufficiently accurate to allow calculation of centimetres. This removal of decimal places has been adopted throughout the document, when referring back to Spiller (1990).

Table IV Total distance covered by six referees during various Rugby Union club matches (Adapted from Spiller, 1990)

SUBJECT	DISTANCE COVERED - 1ST HALF (metres)	DISTANCE COVERED - 2ND HALF (metres)	TOTAL DISTANCE COVERED (metres)
A1	3225	2849	6074
B1	1891	1861	3752
C1	2516	2952	5468
D1	1991	2117	4108
E1	2674	2834	5509
F1	2236	2124	4360
MEAN	2422	2485	4879
STD. DEV.	451	427	847

The distances covered in each movement category by every referee and the percentage contribution of each movement pattern to the total distance covered in the work by Spiller (1990) are highlighted in table V.

Table V Distance covered by the referees subject group in each movement category (metres) and the percentage of total distance covered for each movement category (Adapted from Spiller, 1990)

SUBJECT	WALK	WALK (B)	JOG	SIDEWAYS	RUN	JOG (B)	SPRINT	TOTAL
A1	1542 **25.38%**	559 **9.21%**	2839 **46.74%**	310 **5.10%**	742 **12.21%**	66 **1.10%**	16 **0.26%**	6074
B1	858 **22.87%**	434 **11.56%**	1747 **46.54%**	89 **2.36%**	547 **14.58%**	57 **1.51%**	20 **0.54%**	3752
C1	1300 **23.76%**	713 **13.04%**	2309 **42.22%**	388 **7.09%**	632 **11.56%**	107 **1.95%**	19 **0.35%**	5468
D1	922 **22.43%**	508 **12.36%**	2195 **53.42%**	91 **2.21%**	323 **7.86%**	53 **1.29%**	16 **0.75%**	4108
E1	1546 **28.06%**	620 **11.25%**	2710 **49.19%**	144 **2.61%**	425 **7.71%**	50 **0.90%**	14 **0.24%**	5509
F1	716 **16.40%**	428 **9.82%**	2480 **56.88%**	120 **2.75%**	466 **10.68%**	86 **1.97%**	64 **1.46%**	4360
MEAN	1147	544	2380	190	545	70	25	
STD. DEV.	+/- 331	+/- 101	+/- 368	+/- 116	+/- 137	+/- 20	+/- 18	
MEAN	**23.15%**	**11.20%**	**49.16%**	**3.68%**	**10.67%**	**1.45%**	**0.60%**	
STD. DEV.	+/- 3.54	+/- 1.33	+/- 4.80	+/- 1.80	+/- 2.41	+/- 0.40	+/- 0.42	

Spiller (1990) states that 'referees walk, jog and run (forwards and backwards) approximately ninety-five percent of the total game of which approximately fifty percent is by jogging forwards.' From a combination of all these findings Spiller (1990) focuses strongly on the aerobic loading placed on the physiological systems of the official. The fitness programmes and testing protocols are based around this supposition, with a tendency to ignore making many recommendations relating to the high intensity zone of the referees' workload.

In contrast to this viewpoint are the findings by Reilly (1990), where it is stated that 'soccer play calls for an oxygen uptake corresponding roughly to 75% $\dot{V}O_2$ max, a value likely to be close to the anaerobic threshold of top soccer players.' This has been allied to the fact that 'measurements on thirteen referees during top-class league matches indicated heart rates averaging 165 beats/min during the whole game' (Reilly, 1996).

Therefore there is a possibility that officials in Rugby Union are utilizing the anaerobic energy system and that the aerobic/anaerobic threshold is surpassed on a regular basis during a game. This could not be verified through the work of Spiller (1990), as there was no collection of either heart-rate or blood lactate measurements and the relating of these to the movement patterns in the research. Therefore the validity of the prognosis by Spiller (1990) that the vast percentage of the work carried out by a referee is due to aerobic metabolism is open to conjecture at this time.

Associated with this point, it was also very important to relate the individual physical fitness status of the subjects to the results of the baseline laboratory tests. This was due to the fact that a referee who is highly trained and/or has correspondingly high maximum oxygen uptake and OBLA values could find that the 'running' demands of the game are coped with adequately by the aerobic energy system. However on the other hand a referee who has a low level of fitness and/or low oxygen uptake and OBLA values could be placed under a certain degree of demand from the anaerobic pathways during the periods of 'running' activity. Therefore the laboratory results were correlated with the subject's field measures of heart rate and associated OBLA running speeds to the individual referee's fitness levels. Although Spiller (1990) did not analyse the effects of officiating on heart rate, there is a degree of work in other codes of football that utilize this approach.

Earlier research by Murray (1987) into the movement patterns of a group of Rugby League officials in first grade matches utilized the measurement of heart rates to examine the cardiovascular loadings placed on officials during the games as well as recording the distances that the referees and touch-judges covered in the matches. The distances covered by the referees in the research by Murray (1987) are highlighted in table VI.

Table VI Distances covered by New Zealand Rugby League referees (From Murray, 1987)

SUBJECT	DISTANCE COVERED - 1ST HALF (metres)	DISTANCE COVERED - 2ND HALF (metres)	TOTAL DISTANCE COVERED (metres)
A	4057	4023	8080
B	3923	4693	8616
C	5133	4485	9618
D	4742	4391	9133
E	4566	4445	9011
F	4078	4077	8155
MEAN	4417	4352	8768
S.D.	+/- 434	+/- 234	+/- 546

It is interesting to observe that the research of Murray (1987) calculates that for a Rugby League official 'the average distance covered .... by a referee is 8768 metres with a range of 8080 to 9618 metres' and that 'referees run approximately 90% of the total game compared to 66% for touch judges.'

These results show a 79.7% increase on the distance covered by rugby union referees (Spiller, 1990), illustrating the more continuous nature of the code of rugby league.

This is also the only research that has highlighted the demands of the game on the touch-judges and Murray (1987) found that the average distance covered by a touch judge 'is 5684 metres with a range of 5503 metres to 5864 metres'. However the validity of the study was undermined by the fact that only two subjects were analysed. The distances covered by the touch-judges are illustrated in table VII.

Table VII Distances covered by New Zealand Rugby League touch-judges (From Murray, 1987)

SUBJECT	DISTANCE COVERED - 1ST HALF (metres)	DISTANCE COVERED - 2ND HALF (metres)	TOTAL DISTANCE COVERED (metres)
A	2846	3018	5864
B	2728	2775	5503
MEAN	2787	2897	5684
S.D.	+/- 59	+/- 122	+/- 181

Following the initial findings of Murray (1987), one of the aims of the study is to analyse the work rates of a top flight touch judge in the Rugby Union code, so that recommendations for the physical training and testing of the touch judges can be made based on empirical evidence. As the duties of the touch judges are consistently being expanded under the guidance of the RFU and the game of Rugby Union continues to increase in pace and continuity, it is to be expected that the physical demands on touch judges will grow.

Finally the research by Murray (1987) is useful in identifying whether a similar type of game elicits heart rate levels that would indicate high work demands throughout the match. The results show that the heart rate of officials during the entire game varies between 83-96% of maximum, with an average of 91%, for referees and 69-87% of maximum, with an average of 78%, for touch judges. These findings demonstrate that 'the cardiovascular demands on referees are undoubtedly considerable' and those on the touch judges 'are significant', (Murray, 1987).

When looking to analyse more closely the relative contributions of the aerobic and anaerobic energy systems it is necessary to calculate the rate of oxygen consumption during the exercise for an estimate of the aerobic demand and the two most common methods for estimating anaerobic effort involve either the examination of post-exercise oxygen consumption or the analysis of the lactate threshold.

However the use of these methods for the purposes of field research have their problems, which will be discussed herein. Firstly the assessment of the oxygen consumption of an official during a game cannot be obtained directly, due to the unwieldy nature of the equipment necessary for this style of measurement. However it is possible to use the telemetering of heart rate, for under submaximal work loads this variable is linearly related to the work performed and to the amount of oxygen consumed per minute ($\dot{V}O_2$). This relationship is illustrated in figure 2 and table VIII.

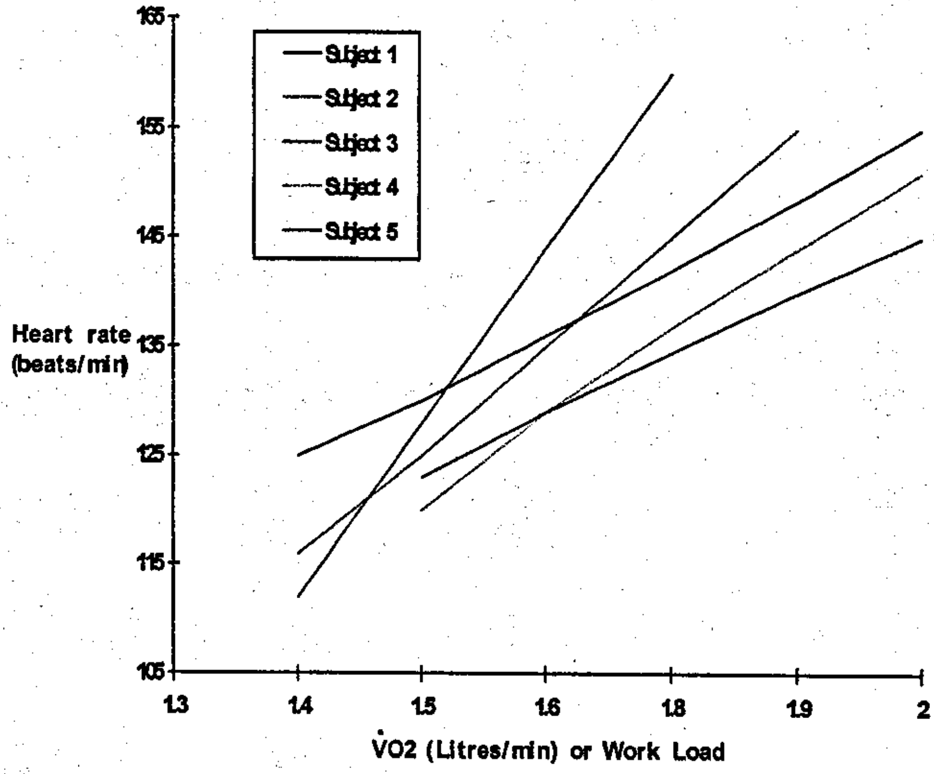


Figure 2 Relationships that exist between work load, $\dot{V}O_2$ and heart rate, indicating variability that exists between individuals. (From Fox et al, 1993)

Table VIII The relationship between the variables of $\dot{V}O_2$ max, maximum heart rate and heart rate reserve. (From Powers and Howley, 1997)

% Max $\dot{V}O_2$	%HRR	% Max HR
50	50	66
55	55	70
60	60	74
65	65	77
70	70	81
75	75	85
80	80	88
85	85	92
90	90	96

This relationship allows for an estimate of $\dot{V}O_2$ cost of the activities that an official undertakes when linked to the laboratory measurements of oxygen uptake and the heart rates elicited by carefully monitored workloads. It is therefore possible to have each official monitored on a treadmill at gradually increasing workloads, with measurements of heart rate and oxygen consumption taken at each work load and using a statistical regression plot the relationship that exists between $\dot{V}O_2$ and heart rate, as in figure 2. Each official can then be fitted with a heart rate transmitter and receiver, which will record and store data throughout the duration of a match. In this manner it is possible to estimate $\dot{V}O_2$ for any time period during the match.

This strategy has been used in a variety of contexts, particularly recently for assessing the physiological workload in Association Football. Reilly (1996) states that 'whilst the limitations of extrapolating from laboratory to field data, using HR-$\dot{V}O_2$ regression lines, suggest that this figure may represent an overestimate, comprehensive calculations indicate that this error is not very large.' In addition to this belief, Lothian and Farrally (1995) discovered that 'heart rate analysis overestimated the true cost by a mean of 4.3%' in the game of Field Hockey, and that 'heart rate cannot be used to predict oxygen uptake at a specific point in time, as the heart rate response is slower and less extreme than the changes in activity.'

Christmass et al. (1998) also state that 'factors confounding the relationship between heart rate and $\dot{V}O_2$ during intermittent exercise should be considered.' One of these factors is that heart rate is not immediately representative of the work conducted and that there can be large changes in the intensity of the exercise and heart rate can remain relatively stable when these periods are of a brief duration. Christmass et al. (1998) also report that the overestimation of $\dot{V}O_2$ from heart rates during intermittent exercise could be as high as 17% in contrast to the 5% error reported by Bangsbo (1994) during continuous treadmill running.

However in supporting the use of this protocol, Lothian and Farrally (1995) state 'heart rate analysis is a good method of estimating oxygen uptake during intermittent exercise typical of team games' and is a 'much better indication of oxygen uptake during intermittent activity than time-motion analysis.' Christmass et al. (1998) also support the use of heart rate to $\dot{V}O_2$ prediction as 'an index of average exercise intensity.'

In conclusion, Reilly (1996) states that 'allowing for any imperfections in such extrapolations from laboratory to field conditions, the heart rate is a useful indicator of the overall physiological strain during play.'

The anaerobic contribution, as mentioned previously, can be calculated by the post-exercise oxygen consumption or the lactate threshold. When examining the concept of the post-exercise oxygen consumption or, alternatively, the 'oxygen debt' (Lamb, 1984), it has to be borne in mind that there are difficulties when using this method to assess the anaerobic system's contribution to the energy yield required for intermittent, long-term exercise.

Firstly the classical explanation of EPOC is too simplistic. For instance, part of the oxygen that is consumed during recovery is utilized to replenish the oxygen taken from the stores located in haemoglobin and myoglobin at the start of exercise. Also respiration remains elevated during recovery to enable the removal of carbon dioxide that has accumulated in the tissues as a waste product of aerobic metabolism. Body temperature has also been elevated during prolonged exercise and this has a tendency to maintain the metabolic and respiratory rates at an artificially high level. Alongside this is the fact that elevated levels of epinephrine and norepinephrine in the body also have similar effects on post-exercise oxygen consumption. Thus more is involved in creation of the EPOC than just the processes resulting from anaerobic metabolism and this oxygen debt can sometimes be twice as great as the oxygen deficit.

The other problem with utilizing the post-exercise oxygen consumption method is that the procedure relies on the exercise being continuous, with no periods of rest breaking up the subject's exercise. However as has been discussed previously it can be seen that the exercise pattern of an official within the game of rugby is intermittent, with periods of high-intensity exercise being interspersed with periods of low-intensity exercise and rest.

During the first few minutes of exercise the body's oxygen consumption would be very similar to that elicited by continuous exercise, as the cardio-vascular and respiratory organs take time to adapt to the demands of exercise. However after this period there will be bouts of high-intensity exercise, such as the referee cruising between phases of play, which will take the energy requirements above the steady state seen in continuous, sub-maximal exercise.

These sporadic periods of play will be interspersed by phases of low-intensity exercise, such as jogging and walking, and periods of rest, where the referee undertakes no locomotive activity. Here there will be recovery from the high-intensity bouts of exercise and the oxygen consumption will drop, mirroring the effects seen in the EPOC at the end of continuous exercise, where lactic acid will be removed and phosphogen stores replenished. These periods of low-intensity exercise and rest will allow the official to recover and prepare physically for the next period of intensive exercise.

Therefore the method of using post-exercise oxygen consumption as an accurate and reliable method of analysing anaerobic metabolism is to be disregarded on both practical and theoretical grounds. Following this the method of using the lactate threshold for the purposes of this research should now be examined as an alternative and viable means of assessment.

There have been a multitude of terms and associated definitions for the lactate threshold. Wilmore and Costill (1994) define lactate threshold as 'the point at which blood lactate begins to accumulate above resting levels during exercise of increased activity.' The concept is described as 'the anaerobic threshold' by Fox et al (1993) and is defined as 'that intensity of work load or oxygen consumption in which anaerobic metabolism is accelerated'. Astrand and Rodahl (1986) stated that 'the concept' of 'anaerobic threshold or onset of blood lactate accumulation is based on an exponential increase in blood lactate concentration when exceeding a certain rate of exercise/oxygen uptake.'

As exercise commences at a light to moderate level, blood lactate remains only slightly above resting levels (0.9 - 1.5 mmol/l). However as the intensity of the exercise is increased there is a point at which blood lactate accumulation begins to increase dramatically above resting levels. At this time pulmonary ventilation, which up until then has increased regularly in a linear manner, increases more sharply than oxygen uptake. This is the lactate or anaerobic threshold and is also known as the 'ventilation breaking point.' (Lamb, 1984). This is usually observed as an upward break in blood lactic acid accumulation to a concentration of around 2 mmol/l and has been determined to occur around 75% of $\dot{V}O_2$ max in well-trained athletes and around 40-60% in untrained, sedentary individuals. Powers and Howley (1997) state that 'this appears in untrained subjects around 50-60% of $\dot{V}O_2$ max, while it occurs at higher work rates in trained subjects (i.e. 65-80% $\dot{V}O_2$ max)'.

A second breaking point in both ventilation and lactic acid can often be observed at a higher level of exercise and is usually associated with a lactic acid concentration of around 4 mmol/l of blood. This level is often referred to as the onset of blood lactate accumulation (OBLA) and has been demonstrated to exist at approximately 81-94% of $\dot{V}O_2$ max in well-trained distance runners.

The physiological cause for this response was initially believed to be due to the interaction of the aerobic and anaerobic energy systems and the switch over towards anaerobic glycolysis as the major energy system. This results in a lactic acid accumulation in the blood and the excess hydrogen ions associated with the build up of acid need to be neutralized.

There is presently a great deal of discussion about the validity of the anaerobic threshold measurement, as 'at least a portion of the increased lactic acid may be related to factors other than increased production of lactic acid.' (Lamb, 1984). These other factors may include a diminished removal of lactic acid from the blood or a reduction in the utilization of lactic acid, possibly by the reduced blood flow to the kidneys as exercise progresses. Lamb (1984) also states that 'the accumulation of lactic acid could simply reflect the increased recruitment of fast twitch motor units that have poor capacities for aerobic energy production.'

This viewpoint is supported by Powers and Howley (1997) who states that NADH production caused by rapid glycolysis 'may exceed the transport capacity of the shuttle mechanisms that move hydrogen ions from the sarcoplasm into the mitochondria.' This would mean that pyruvic acid accepts 'unshuttled' hydrogen ions and thus lactic acid production would occur regardless of whether the muscle cell has sufficient oxygen for aerobic production.

Therefore much of the current research has avoided use of the term 'anaerobic threshold' and looks instead to use either the 'ventilation breaking point' or 'onset of blood lactate accumulation' in an attempt to clarify this issue.

Although the concept of OBLA has its theoretical problems, with Astrand and Rodahl (1986) in particular stating that 'the threshold concept rests on an unstable foundation' and 'the importance of the threshold concept as a coaching guide awaits scientific evaluation', it is still considered the best method for assessing the quantity of anaerobic work that an athlete undertakes during exercise and was therefore adopted for the purposes of this research.

The arbitrary level of 4 mmol/l of blood is currently accepted as the OBLA by most research and is the level selected for the basis of this work. Astrand and Rodahl (1986) support this by stating that 'in many laboratories the testing has been standardised with the goal of finding the rate of exercise or oxygen uptake at which the blood lactate concentration reaches a value somewhere between 2.5 and 4 mmol/l.'

When considering the relationship between oxygen consumption and heart rate, expressed as a percentage of the maximum value for each component, it becomes clear that Murray's (1987) statement is correct, as 83-96% of maximum heart rate is predicted as the equivalent of 78-90% of $\dot{V}O_2$ max, a value that would place a major stress upon the aerobic system, as well as calling upon the anaerobic system.

Unfortunately this research only relates the heart rates measured during the game to those achieved at the maximum level during the oxygen uptake test and not to the heart rate above which an onset of blood lactate (OBLA) is seen, so it is difficult to estimate the actual time spent by each referee at or above their OBLA level during a match.

However Lamb (1984), states that the first onset of blood lactate accumulation occurs at around '150 beats per minute' with an increase of blood lactate accumulation above 4 millimoles per litre of blood (mmol/l) being 'detected at a heart rate of 170-190 beats/ min.'

As the officials in the study by Murray (1987) are working for the majority of the matches at an average of approximately 150-173 beats/min it would be reasonable to hypothesize that there is a considerable portion of work that is being performed above the OBLA level, but the exact percentages cannot be calculated from this work.

It is therefore the purpose of this research to bring in heart rate measurements recorded during the games and link them to the movement patterns of the officials and their heart rate and OBLA responses during the maximum oxygen uptake and speed lactate tests, so that the ratios of aerobic and anaerobic metabolism during a match can be examined. This method has been used as a reliable index of average exercise intensity during intermittent exercise (Smith et al., 1993; Bangsbo, 1994). However Christmass et al. (1998) has observed that 'during intermittent exercise ...... heart rate may be elevated beyond the HR-$\dot{V}O_2$ relation seen in continuous exercise owing to higher circulating catecholamine levels and accumulation of metabolic byproducts such as carbon dioxide.' Care must therefore be taken when calculating the physiological demands placed on officials, based upon heart rate measurements, in an intermittent-style game.

When utilizing the work undertaken in the code of Rugby League it must be borne in mind that this game has undergone a similar revolution to that of Rugby Union. Since the work of Murray (1987), there have been radical alterations to its overall structure which will have, in all probability, affected the current validity of the data from this research. Satellite television has brought about the advent of 'Super League' and this massive investment in the sport has dealt changes to the attitudes of players, coaches and officials involved in the sport. Realizing the need for increased entertainment value from this sport, the laws of the game and the overall playing policies affecting the sport have meant an increased intensity and physical workload for the players and officials.

It is therefore interesting to analyse, using recent research within the code of Rugby League, whether there have been significant improvements in the quality of the work done by officials.

Such a study into referees movement patterns in the code of Rugby League, by HealthPac (1995) showed that 'the average total distance covered during an 80 minute game was 10,293 metres with a range of 7,876 metres to 11,970 metres.' This research shows that there has indeed been an increase in the average total workload of the referee of 17.4% from the previous research some seven seasons earlier. The total distances covered by the referees in the HealthPac (1995) research is shown in table IX.

Table IX Distances covered by Rugby League referees in a match (From HealthPac, 1995).

SUBJECT	DISTANCE COVERED - 1ST HALF (metres)	DISTANCE COVERED - 2ND HALF (metres)	TOTAL DISTANCE COVERED
A	5815	5433	11248
B	5976	5994	11970
C	3964	4224	8188
D	5950	5080	11030
E	5327	5023	10350
F	3797	4079	7876
G	5617	5803	11420
H	4837	5431	10268
MEAN	5160	5133	10293
S.D.	+/- 818	+/- 644	+/- 1406

The research findings of HealthPac (1995) also included the measurement of heart rates elicited during the game. It was discovered that the mean heart rate during the entire game for a referee was 157 beats/min, with an mean range of between 119 to 175 beats/min. This is calculated to be, as a mean, 86% of the selected referees' predicted maximum heart rate, with an mean range of between 65 to 96% of the predicted maximum. This is lower than the results from Murray (1987), which showed a mean of 91% of maximum heart rate throughout the match, with an mean range of 83 to 96% of maximum heart rate.

This apparent reduction in mean heart rate from the earlier research appears to be contradictory to the fact that the workload, in terms of distance covered, has increased. However one factor in this discrepancy could be an increase in referees' fitness over the intervening years, as the game has changed in its professional outlook, resulting in a greater ability to cope with the physical stress imposed upon the subjects during the matches.

Also the studies differed in the methods of determining the maximum heart rates of the subjects. Murray (1987) calculated the subjects' peak heart rate by obtaining recordings from a heart rate monitor whilst the subject performed a maximal oxygen uptake test, whereas the HealthPac (1995) study estimated the maximum heart rate using the formula: 220 - age.

The HealthPac (1995) method of estimation has, when referring to the earlier work by Astrand and Rodahl (1986), been cited as having a large degree of error, with the chances being that the estimate is 5 to 10 beats/min outside of the absolute maximum. Powers and Howley (1997) support this when stating that 'the age-adjusted HR maximum estimate has a potential error equal to +/- 11 beats/minute.' This therefore throws the heart rate findings of HealthPac (1995), in terms of the published average percentages of the subjects' maximal, into some doubt.

However what is certain is that the sport of Rugby League has increased its workload demands, in terms of distance covered, in the last few years. With the sport of Rugby Union also having undergone similar structural changes within the past five seasons, the evidence from Murray (1987) and HealthPac (1995) supports the hypothesis that there will have been a related increase in the physical demands on the Rugby Union officials.

However whenever the two rugby codes are compared and research from one is used to support hypotheses in the other it is important to realise that there are a number of crucial movement pattern discrepancies to be borne in mind. For instance, Murray (1987) recorded an average 10.77% (934 metres) contribution by the movement pattern of jogging backwards, which has increased to 20.4% (2097 metres) in the research by HealthPac. This is significantly different to the findings of Spiller (1990), where only 1.5% (70 metres) of the physical work in Rugby Union refereeing was performed by jogging backwards.

In further discussion of the high intensity workload of an official, when considering the necessity and relevance of measuring blood lactate values educed by the demands of the game, it is important to draw upon the findings of McLean (1992) and Deutsch at al (1998). McLean (1992) found that when the blood lactate concentrations of first division players were analysed at fifteen minute intervals throughout a game that 'the BLa (blood lactate) analysis carried out in this study confirms that anaerobic metabolism is required for playing Rugby Union' (McLean, 1992). When monitoring three positions in the game, McLean discovered that measurements of between 5.8 - 9.8 mmol/l of blood lactate were recorded, which exceeds the proposed OBLA level of 4 mmol/l (Jacobs, 1981). From these results McLean (1992) concluded that 'the game places greater demands on anaerobic glycolysis than previously reported.'

Deutsch et al (1998), in a study which focused on the blood lactate data collected from 24 colts (under 19) players during six competitive Premiership fixtures, discovered that there was a mean blood lactate concentration of 4.8 – 7.2 mmol/l in blood sampled once or twice during each half and at half- and full-time which 'indicated a considerable contribution from anaerobic glycolysis to match performance for all players.' Alongside of these results heart-rate data in these matches suggested that 'props, locks and back-row forwards may spend up to 20% of match time above 95% of maximum competitive heart rate.' (Deutsch et al, 1998).

Although this contradicts the research by Docherty *et al.* (1988), who reported levels of only 2.8 mmol/l (s.d. +/- 1.62 mmol/l) in players, the measurements in Docherty *et al*'s (1988) work were only single samples taken 5 minutes after the completion of the game and it is likely that this time delay would have allowed time for any blood lactate produced in the match to be metabolized. Also the level at which the players were taking part was lower than that of the McLean (1992) and Deutsch et al (1998) studies, tending to imply that the relative work intensity and thus the demands placed upon the anaerobic energy pathways of the Docherty et al (1988) study would have been reduced accordingly.

It would appear that there is some controversy still existing over the values of blood lactate and the associated contribution of the anaerobic pathways in the code of Rugby Union and this issue, as it pertains to officials, will be addressed later in the study.

CHAPTER 3

PILOT STUDY

3. 1. Introduction to the methodology of the study

To test the proposed hypotheses this investigation took a representative sample of top RFU officials, both referees and touch-judges, and evaluated a number of base-line physiological variables using laboratory testing procedures, including the measurement of maximum oxygen uptake, OBLA levels and associated heart rates.

These results were used in conjunction with physiological variables attained during a number of level 1 and 2 matches to assess the individual work rates and physiological demands placed on the officials. Level 1 matches were defined as those equating to games involving Premier Division teams and Level 2 matches were defined as those equating to games involving Division One teams.

A combination of video camera coverage of the matches and heart rate data was collected concurrently in those games. The videotape recordings were then used to analyse their movement patterns and detailed, reliable post-match analysis of the tapes carried out and related to the relevant officials' physiological variables to calculate the demands placed on them during these matches. It was intended that the heart rate would be monitored prior to, during and after the match. These results were then assessed against the physiological measurements taken in the laboratory and comparisons drawn from this data against the proposed hypotheses.

It was anticipated that from these results a number of recommendations could be made for future use in devising appropriate and relevant fitness programmes. Finally these fitness programmes would be assessed for their effectiveness using a sample of subjects and their relevance applied to a designed fitness test specific to the match fitness required for Rugby Union officials.

3. 1. 1. The aims of the pilot study

A pilot study into the physiological demands of officiating at a lower level was performed in order to assess the viability of the proposed study. In the pilot study a sample of two local matches were video recorded for the following objectives:

i) To practise collecting and analysing video footage obtained from the games to calculate the different work loads imposed upon an official.

ii) To examine the viability of taking heart rate and blood lactate measurements from officials before, during and after the selected matches.

iii) To examine the reliability and validity of this methodology of data collection and the comparison of results obtained in relation to other literature in this field of research.

iv) To allow assessment of the practicalities associated with this research and to ensure that problems with data collection are avoided as much as is possible when the main body of research was being carried out.

Various methods for the collation of relevant physiological data were considered. As stated earlier in chapter one, the mechanics of the energy continuum and the interaction of the three energy systems (ATP-PC, lactic acid/anaerobic and aerobic) in the provision of ATP for physical work, provided a starting point for the understanding of the physiological processes involved in performing various activities in a Rugby Union match.

The problems surrounding movement analysis of an individual during an invasive game are well documented. The major difficulty arose from the need to assess the distances covered in a sport where absolute measures of accuracy are highly problematic. The use of video recorders and play-back facilities allowed the processing of movement analysis without directly interfering with the referees/touch-judges performance of their in-match duties and it enabled repeated viewing of the same match to ensure reliability of measurement.

Much of the research has stemmed from the initial work by Reilly and Thomas (1976) in Association Football and recently this work was developed further by Murray (1987) in the code of Rugby League. The methods used by the researchers involved video recording the subject from an elevated position in the spectators' standing area for the whole of the game and then recounting the number of strides taken, at different speeds, at a later date. This method was seen as the most viable and accurate currently available.

During the pilot study two officials, both referees, were assessed using a video camera mounted on a tripod at two differing vantage points to firstly establish which position would provide the most effective method of recording the various movement patterns during the matches to follow and secondly to enable the accurate quantification of distance covered to be calculated. The distance covered via the different types of travel, the frequency of travel types and the time spent in each of the travel types were calculated using the basis of the definitions developed by Docherty *et al* (1988), Mayhew and Wenger (1985) and adapted for use with officials within the code of Rugby Union by Murray (1987) and Spiller (1990).

Locomotion activities were coded into the following categories :

1) Standing :	No locomotor activity
2) Walking :	Forward strolling locomotor activity
3) Jogging :	Non-purposeful, slow running in which no effort was made to stride or accelerate
4) Running :	Locomotor activity with an elongated, purposeful stride but without full effort
5) Sprinting :	Locomotor activity at or close to maximum speed, with full effort
6) Backwards walking :	As for walking but with backward locomotor activity
7) Backwards running :	As for running but with backward locomotor activity
8) Sideways movement :	As for walking but with sideways locomotor activity

Bangsbo (1994) has also undertaken work in the area of analysing Association Football and the physiological processes involved in this code. When performing match analysis utilizing the methods of Reilly and Thomas (1976), Bangsbo (1994) devised a quantitative method of defining movement categories. The velocities of the various movement patterns established by Bangsbo (1994) are illustrated below:

1. Standing: 0 km/h - 0 m/s

2. Walking: 4 km/h - 1.1 m/s

3. Jogging: 8 km/h - 2.2 m/s

4. Low-speed running: 12 km/h - 3.3 m/s

5. Moderate-speed running: 16 km/h - 4.4 m/s

6. High-speed running: 21 km/h - 5.83 m/s

7. Sprinting: 30 km/h - 8.3 m/s

8. Backwards running: 12 km/h - 3.3 m/s

The pilot study was used to assess the Bangsbo (1994) definitions of the various velocities and the applicability of the values as a tool for assisting a more objective definition of the movement categories in the major study.

3. 2. Methodology

3. 2. 1. Part 1 - Methodology for evaluation of stride length

The stride lengths for the various activities were estimated using a methodology based upon the work by Reilly and Thomas (1976) who stated that 'mean stride lengths were determined ...... by instructing the subjects to cover a distance between two marked points at each type of activity and at a level corresponding to the experimental classification.'

For the purposes of this research this methodology was modified in that the two referees were ordered to proceed a total of ten strides at the various paces and the average length for one stride was then calculated by dividing the total distance covered by ten. This was then repeated a further two times to allow a mean stride length to be obtained over three attempts, in order to enhance reliability. This rationale for obtaining average stride lengths was thought to be more representative of a natural action, as the subject did not artificially alter stride length in order to reach the second of the two marked points.

This method of correlating the distances obtained through a mean stride length assessment to the match video 'is still considered to be the most appropriate way of monitoring one player per game.' (Reilly, 1996).

3. 2. 2. Part 2 - Methodology of the notational analysis

The first match used in the pilot study was not analysed, as this game was used solely for the purpose of familiarization with the video recording equipment and to establish the optimum vantage point for future recordings.

The second match was used to obtain suitable footage for analysis of the distance covered by the referee in the different movement categories. A period of 18.15 minutes, a total of 1095 seconds, was selected for match analysis.

A sheet for the notation of the different movement categories was devised, which allowed a record of stride frequency and number of strides to be tabulated.

Analysis of the referee involved tracking the movements, using a 20 inch Sharp monitor and a Bush Video Cassette Player and recording, on prepared notation sheets, the frequency of each discrete movement type and the number of strides in every single movement phase.

Inspection of the recorded film was conducted over two repeat sessions of approximately three hours in total length, which allowed measurements to be checked for reliability.

3. 2. 3. Statistics

Both the total distance covered and the total time spent in each movement category were tested for reliability using a Pearson's product moment correlation test.

This test was selected on the bases that the data was of a parametric (ratio) nature and the relationship between two variables was being assessed, i.e. the extent to which the size and direction of the deviations from the mean in one variable (the first measurement) are related to the size and direction from the mean in the second variable (the second measurement). To ensure statistical rigour a 99% level of confidence was applied to the test ($p<0.01$).

The definition formula for Pearson's product moment correlation coefficient (r) is :

$$r = \frac{\Sigma[(Zx)(Zy)]}{N}$$

where: Zx and Zy are the Z scores for each subject on the X and Y variables

N is the number of pairs of scores

3. 2. 4. Part 3 - Methodology of the movement analysis

To calculate the total distance covered by each movement pattern the average stride length was multiplied by the total number of strides recorded for that activity. Alongside this the total duration of each movement pattern was determined using a hand held stopwatch and finally the average time and distance per movement period was calculated.

3. 2. 5. Part 4 - Methodology of the heart rate analysis

Following this preliminary research two matches at the beginning of the 1996-97 season were used to assess the viability of monitoring the officials' heart rates via short range telemetry (using a Polar Vantage heart rate monitor).

Whilst the subjects performed their duties, the monitor recorded and saved heart rate measurements every 5 seconds, beginning five minutes prior to the commencement of the match and carrying on recording until the researcher could remove the device at a convenient time soon after the completion of the game.

These measurements were then downloaded on to a computer (IBM 486) using a Polar Advantage Interface System and ultimately analysed using the associated Polar Precision Performance Software. The first match examined the heart rate measurements of a referee, while the second match looked at the physiological effects upon a touch judge.

3. 3. Results

3. 3. 1. Part 1 - Results of the stride length analysis

Table X reflects the mean stride lengths of the two referees involved in the pilot study. It was decided that the average stride length would be used when analysing the video footage of the pilot study match, as this would help to make the stride lengths more representative in an isolated situation and cut down on individual differences of the two referees' stride patterns.

Table X Stride length of subjects (in metres) analysed during different movement patterns

SUBJECT	Walking	Jogging	Running	Sprinting	Walking (Back)	Running (Back)	Sideways
A	1.00	1.54	1.88	2.02	0.84	1.10	2.10
B	0.90	1.55	1.77	1.77	0.88	1.55	1.76
Average	0.95	1.545	1.825	1.895	0.86	1.33	1.93

3. 3. 2. Part 2 - Results of the notational analysis

Table XI shows an example of the notation sheet used for recording the various movement styles and their frequencies. The complete notation sheets obtained from the pilot study research are outlined in Appendix A.

Table XI Sample notation sheet for analysis of referee's movement patterns

MOVEMENT PATTERN	FREQUENCY	NUMBER OF STRIDES
Walking	IIIII IIIII	6/17/18/10/13/2/5/1/4/8/ etc.
Jogging	IIIII	26/14/22/18/16/etc.
Running	I	4/etc.
Sprinting	I	3/etc.
Walking (Back)	IIIII	4/4/7/2/1/etc.
Jogging (Back)	I	1/etc.
Sideways	III	1/2/4/etc.
Standing	IIIII	Xxxxxxxxx

3. 3. 3. Part 3 - Results of the movement analysis

Table XII illustrates the total frequencies, time spent, distance covered, average time and average distances per movement period recorded from the initial assessment of the pilot study footage.

The repeated measures of the data to check reliability of this method of data analysis, using a Pearson's product correlation test, found a significant correlation between the total distances covered ($r=0.99$, $p<0.01$) and the total time spent in each movement category ($r=0.99$, $p<0.01$) from one session to another. The tabulated data for the two sessions is displayed in table XIII and the raw data for the Pearson's test is detailed in Appendix O(i).

Table XII Total and mean distances and times covered by different movement categories in the pilot study video

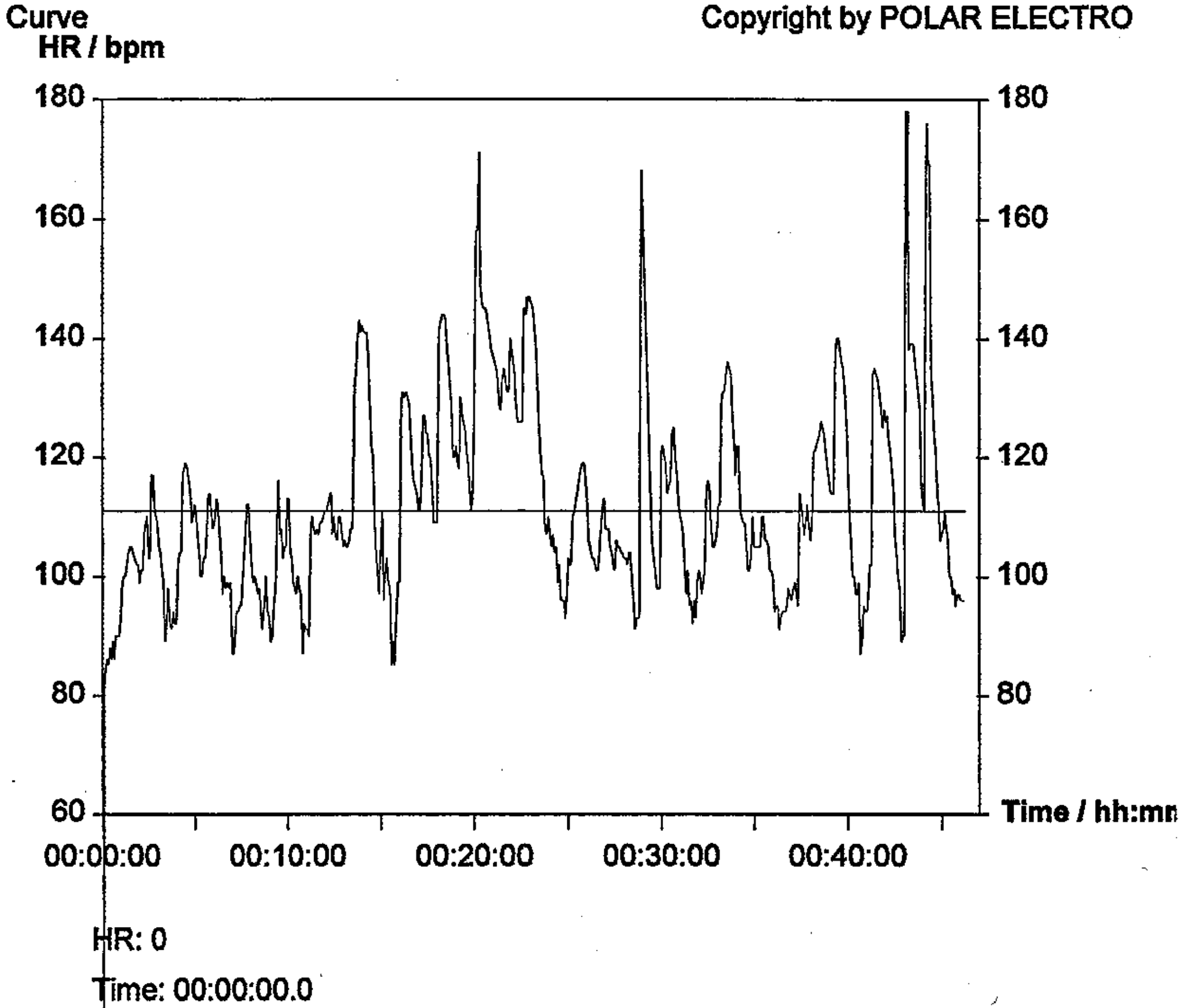
MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	MEAN DISTANCE PER MOVEMENT (metres)	MEAN TIME PER MOVEMENT (seconds)	MEAN VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED (%)	PERCENTAGE OF TOTAL TIME SPENT (%)
Walking	106	712	422	7	4	2	35.1	38.5
Jogging	37	760	182	21	5	4	37.4	16.6
Running	8	206	35	26	4	6	10.2	3.2
Sprinting	4	64	10	16	3	6	3.2	0.9
Walking (Back)	71	213	130	3	2	2	10.5	11.9
Jogging (Back)	3	11	4	4	1	3	0.52	0.4
Sideways	18	64	16	4	1	4	3.1	1.5
Standing	82	0	295	0	4	0	0	27.0
TOTALS	320	2030	1095	6	3	1.85	100	100

Table XIII Total distances and times covered by different movement categories in the repeat analysis sessions of the pilot study video

	ANALYSIS SESSION 1		ANALYSIS SESSION 2	
MOVEMENT PATTERN	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)
Walking	712	422	730	434
Jogging	760	182	741	191
Running	206	35	189	39
Sprinting	64	10	71	11
Walking (Back)	213	130	224	120
Jogging (Back)	11	4	9	4
Sideways	64	16	73	18
Standing	0	295	0	304
TOTALS	2030	1095	2037	1121

3. 3. 4. Part 4 - Results of the heart rate analysis

Figure 3 shows the results of the touch judges' heart rate from the second of the two analysed matches.



Person	KP	Date	28/09/1996	Average	111 bpm	Recovery	0
Exercise	1996/09/28 15:39:32	Time	15:39:32	Duration of exercise: 00:46:11.4			
Note	Touch judging on a level 2 league game						

Figure 3 Heart rate measurements recorded from a touch-judge during the second half of a rugby match through use of a Polar Vantage NV heart rate monitor.

3. 5. Discussion of pilot study findings

A number of points were highlighted by the findings of the pilot study. The format of the initial notational sheets used in the pilot study were not sufficiently detailed for the purposes of this research and that a more advanced notational sheet was designed for the major part of the study. This is outlined further in chapter four of the major study.

The establishment of the stride lengths for each referee needs to be carefully monitored to ensure that a high degree of representation of the movements made during a match are reflected by the stride lengths recorded in isolation. This is a key point as it was felt that the distances recorded from the video were over exaggerated, particularly in the walking category, as the referee in the match did not appear to stride in the same manner as the two subjects in the stride length determination study. This problem was addressed in the main study by attempting to correlate the subjects' video movements with their stride patterns in the isolated determination of the stride lengths as closely as possible.

Also when establishing the range of velocities for each movement category the pilot study differed in some respects to the precise values determined by Bangsbo (1994). However the comparisons drawn from the preliminary study allowed a range of velocities to be ascertained for an improved, objective analysis of the movement patterns of the subjects to supplement the established, subjective definitions of the patterns in the main study. This allowed for a more rigorous and valid determination of the officials' total distances in each movement category.

The pilot study encompassed many of its stated objectives, with essential practice in video recording carried out and its derivative data collection methods being scrutinized for purposes of accuracy and familiarity. The reliability of the adopted method for assessment of the total distance covered and the total time spent in each movement category was found to be good ($r=0.99$; $p<0.01$) and was used in the main study.

The pilot study demonstrated that the equipment proved to be reliable in collecting repeated heart rate information over a prolonged period and that the methodology for collecting heart rate data was relatively straightforward. This method was therefore adopted for the main study and would result in some valid measurements that would allow for a full investigation into the physiological stresses placed upon the officials during a match.

It was hoped that the measurement of blood samples at convenient periods during the matches would also be taken, alongside heart rate measurements, in order to allow comparisons of blood lactate levels elicited by the demands of the game to be made with previous research. However due to the practical difficulties of taking these invasive measurements it was decided that blood lactate measurements in the main body of the research would not be taken.

This was due mainly to the fact that only three measurements would be feasible - just prior to the match, at half-time and as soon as possible after the completion of the game. It was felt, after the pilot study was conducted, that this approach would be impractical.

Also due to the fact that lactate measurements are reflective of the work undertaken by the subject just prior to the blood sampling, it was thought that such measurements would not mirror accurately the overall lactate production from anaerobic metabolism during a game.

3. 6. Limitations and assumptions for testing

From the data collected during the pilot study and the findings arising from this preliminary research, the following limitations were put forward for the match and laboratory analysis of the officials:

i) The number of subjects taken within the sample were considered to be sufficiently large to be representative of the RFU National Panel of referees and touch-judges.

ii) The officials chosen were selected according to their current status on the RFU National Panel, with the need for the sample group to be officiating in level 1 and 2 matches.

iii) The validity of the subjects laboratory measurements is ultimately dependent upon the motivation of the subjects to perform to the highest level that is possible (Clinton, 1963, and Safrit, 1973). It was assumed that all subjects attempted to perform to their physiological maximum.

iv) Due to problems with travelling and availability of the subjects, it was assumed that a single test procedure would give valid results and the reliability of results thus obtained would be based on previous studies using such laboratory methodology.

3. 7. Limitations and assumptions for movement analysis

i) It was assumed that the matches video recorded were not a-typical of representative level 1 and 2 matches.

ii) The greatest difficulty in analysing movement patterns from video format is the differentiation between the categorization of 'running' and 'jogging' activity. Definitions that have been utilized in previous studies are that 'running' is seen as moving forwards at threequarters of one's maximum speed and that 'jogging' is a non-purposeful activity. This study allows for the definition of 'jogging' as non-purposeful, slow running in which no effort was made to stride or accelerate and as having a range of between 2-4 metres per second. 'Running' was defined as locomotor activity with an elongated, purposeful stride but without full effort and as having a range of between 4-7 metres per second. These definitions were adopted from Bangsbo (1994).

CHAPTER 4

MATCH AND LABORATORY ANALYSIS OF REFEREES

4. 1. METHODOLOGY

4. 1. 1. Introduction

The study aimed to examine the physiological loadings placed on the officials, both referees and touch-judges, whilst performing their duties during a high level game of Rugby Union.

The testing of the referees involved the recording in the game of all movement patterns and associated physiological variables, e.g. heart rate, elicited by a level 1 and/or level 2 match. The results from the field measurements will be correlated with a range of laboratory test results to assess the relative physiological stress placed on each official.

4. 1. 2. Subjects

Ten subjects were selected from the RFU National Panel of referees to be analysed in both the field and the laboratory tests. The subjects were chosen from the group of officials selected by the RFU to perform in level 1 and 2 matches during the seasons of 1996/97 and 1997/98.

The basic physiological characteristics of the subject group are displayed in Appendix B.

4. 1. 3. Movement analysis

Ten referees were selected as subjects according to their placement on the RFU Panel and the fact that they would officiate as both a referee and a touch-judge at level 1 and/or 2 at some period during the study. All subjects were video recorded performing as a referee once and a touch-judge once during the 1996/97 and 1997/8 seasons.

Permission from the Clubs concerned was agreed prior to the commencement of the video analysis. The Clubs involved in the study were :

Harlequins R.F.C.	Northampton R.F.C.	London Scottish R.F.C.
Sale R.F.C.	West Hartlepool R.F.C.	Bristol R.F.C.
Orrell R.F.C.	Oxford University R.F.C.	Bath R.F.C.
Bedford R.F.C.	Rotherham R.F.C.	

The video camera used for recording of the officials was a Panasonic AG 455 Pro-Line. Each match was recorded from an elevated position in the spectator's standing area, usually with as high a position as was possible, to avoid obstructions such as spectators obscuring the view. Wherever possible the referee was video recorded from a position half-way along one of the touch-lines, which enabled either side of the pitch to be equidistant from the video camera. The touch-judges were video recorded from a placement located behind the goal posts at one end of the ground. This allowed the tracking of the touch-judges on the touch-lines to take place without obstruction from the stands or spectators, as the positioning of the touch-judges for a large percentage of the game would have created problems if recorded from a sideways position.

To determine the physiological demands placed on the subjects the workload in terms of distance covered was calculated using the system of examination outlined in the pilot study and developed according to the findings from that part of the study.

As outlined previously, analysis of the referee involved tracking the movements, using a 20 inch Sharp monitor and a Bush Video Cassette Player and recording, on prepared notation sheets, the frequency of each discrete movement type and the number of strides in every single movement phase. The definitions of each movement category used in the main study were an amalgam of the descriptive terminology used by Docherty *et al* (1988), Mayhew and Wenger (1985), Murray (1987) and Spiller (1990) and the quantitative descriptions of Bangsbo (1994). The definitions of each movement category are outlined in table XIV.

Table XIV Definitions of various movement categories utilised by officials in the code of Rugby Union.

MOVEMENT PATTERN	QUALITATIVE DEFINITION	QUANTITATIVE DEFINITION
1) Standing :	No locomotor activity	0 m/s
2) Walking :	Forwards strolling locomotor activity	0 - 2 m/s
3) Jogging :	Non-purposeful, slow running in which no effort was made to stride or accelerate	2 - 4 m/s
4) Running :	Locomotor activity with an elongated, purposeful stride but without full effort	4 - 7 m/s
5) Sprinting :	Locomotor activity at or close to maximum speed, with full effort	7 - 9.5 m/s
6) Backwards walking :	As for '2) walking' but with backward locomotor activity	0 - 2 m/s
7) Backwards running :	As for '4) running but with backward locomotor activity	2 - 4.5 m/s
8) Sideways movement :	As for '2) walking' but with sideways locomotor activity	0 - 4 m/s

To calculate the total distance covered by each movement pattern the average stride length of the subject being analysed was multiplied by the total number of strides recorded for that activity. Alongside this the total duration of each movement pattern was determined using a hand held stopwatch and finally the average time, speed and distance per movement pattern period was calculated.

In addition to this the total percentage of distance covered and time spent in each movement pattern category was calculated. The analysis sessions were no longer than an hour at a time, in order that a high degree of experimental accuracy could be maintained throughout the study. Periods of analysis longer than this duration were found in the pilot study to result in a reduction in the concentration level of the researcher and invariably reduced the reliability and validity of the final results.

4. 1. 4. Statistics

Once the distance variables had been calculated the results were then compared with the various relevant research to assess whether any significant differences existed and whether statistical acceptance of the hypotheses outlined in the introduction was possible.

Comparison of whether significant differences existed between distances covered in the first half to the second half by referees was calculated by use of a repeated measures t-test (two-tailed). This test was selected on the bases that the data is parametric (ratio), the samples are randomly drawn from the population and the population from which the samples are chosen is normally distributed. In order to avoid errors a conservative ($p<0.01$) level of confidence was selected.

Comparison of whether significant differences existed between the data from this study and previous relevant research was calculated by use of an independent measures t-test (two-tailed). This test was chosen for the same reasons as outlined above and had an identical level of confidence applied.

The basic formula for the t-test is:

$$t = \frac{X_1 - X_2}{SE_D}$$

Where: X_1 & X_2 are the means of the two samples

SE_D is standard error of the difference between the two means

4. 1. 5. Introduction to the laboratory analysis

The subjects performed a series of laboratory and field tests in order to ascertain a number of baseline physiological measurements. The values obtained from the laboratory assessment of maximum heart rate and heart rate at OBLA were then related to the video and heart rate analysis results obtained from the matches, to allow suitable comparisons to be drawn up for discussion on the physiological demands on referees and touch-judges by the game of Rugby Union.

Prior to the physiological assessment all subjects were given detailed information of the tests to be undertaken and a written consent form plus basic medical questionnaire were completed and signed by each subject. These forms are detailed in Appendix R(i) and (ii).

The subjects undertook two treadmill tests, to assess maximal oxygen uptake and associated variables, and carried out the stride length measurement protocol, detailed earlier, to determine the length of an average stride at each of the paces used during the video analysis section. The subjects were assessed in pairs, so that sufficient rest occurred between all tests.

4. 1. 5. 1. The assessment of the onset of blood lactate accumulation (OBLA)

As outlined in the pilot study, the measurement of blood lactate concentration during increasing intensity of exercise gives an indication of the extent to which the muscle has to rely on anaerobic metabolism at a certain submaximal intensity. It was decided, due to the misleading theoretical concept of anaerobic threshold, discussed earlier, that the terminology of 'onset of blood lactate accumulation or OBLA' would be used.

The protocol for obtaining the OBLA level in the subjects is detailed by the British Association of Sport Sciences in the 'Position Statement on the Physiological Assessment of the Elite Competitor' (1988). The test is described as being 'appropriate for players of multiple-sprint games, who need to remove lactate quickly during support running and during recovery periods.'

The reasons for utilizing this protocol were as follows:

- Only five blood samples were required.
- The length of the test protocol was only sixteen minutes.
- Each stage was long enough for measurements of steady-state oxygen uptake and heart rates to be made, so that comparisons could be made between other laboratory and field tests.

Samples of capillary blood were obtained at rest prior to the subjects beginning any of the tests. The test methodology then involved the subject running continuously on a level treadmill for sixteen minutes, during which running speed is increased every four minutes. Duplicate 20 μl blood samples were obtained from the fingertip at the end of each four minute stage and before the treadmill speed was increased, for the subsequent determination of the running speed and heart rate equivalent to a reference concentration of 4 mmol/l. The 20 μl samples were refrigerated and analysed at a later point utilizing the method based upon that of Maughan (1982). The complete methodology is detailed in Appendix S.

Expired air was collected using a Douglas Bag during the final minute of each stage, with heart rate being recorded at fifteen second intervals during the collection of expired air. Heart rate was monitored by short range telemetry (a Polar Vantage NV heart rate monitor) throughout.

To determine the treadmill running speeds for the subjects' four stages, tables were used, which operate on the basis of the subjects' $\dot{V}O_2$ max values from the multistage fitness test. These are illustrated in table XV.

This OBLA test protocol has a recorded test-retest correlation of greater than 0.93 (British Association of Sport Sciences, 1988).

Table XV Suggested exercise intensities for the four-stage incremental test (from British Association of Sport Sciences, 1988)

		Running Speed (m/sec)								
VO2 max (ml/kg /min)	Multi-stage fitness test result (level & stage)	2.24	2.69	3.13	3.58	4.03	4.48	4.93	5.37	5.82
45	9-0	*	*	*	*					
50	10-8		*	*	*	*				
55	12-6			*	*	*	*			
60	14-2				*	*	*	*		
65	15-10					*	*	*	*	
70	17-7						*	*	*	*

4. 1. 5. 2. <u>The assessment of maximal oxygen uptake ($\dot{V}O_2$ max)</u>

Maximum oxygen uptake ($\dot{V}O_2$ max) was determined from an incremental treadmill exercise test to volitional exhaustion and the following criteria were considered to ensure the validity of the readings obtained :

- A final respiratory exchange ratio value above 1.00 and close to 1.15.
- A final heart rate of within 10 beats per minute of the age-related maximum.
- A final value of oxygen uptake that is within 10% of the subjects' previous multi-stage fitness test result.

These criteria were established by the British Association of Sport Sciences (1988). Failure to meet these criteria in the initial test would have resulted in a re-test after a period of rest, e.g. several days.

The treadmill speeds were established using the previous multi-stage fitness test results for each subject and in conjunction with the guidelines from the British Association of Sport Sciences (1988). The aim of the test was to achieve exhaustion within 9-15 minutes of the start of continuous exercise.

After a suitable warm-up of between three and five minutes, at a pace below the test running speed, the subjects began the test by exercising at a constant running speed, related to the predicted $\dot{V}O_2$ max value. The treadmill was set at a starting gradient of 3.5% and after the end of each three minute period the treadmill elevation was increased by 2.5%. Gas collection of expired air was taken using Douglas Bags during the final minute of each stage prior to the increase in gradient. When the subject revealed signs of terminating the test, the mouthpiece and noseclip were retained and on a signal from the subject a final minute gas sample was collected. No gas samples were taken for less than thirty seconds.

A 'rate of perceived exertion' scale (Borg, 1982) was shown to the subject during each gas collection stage, so that the proximity to the end of the test could be constantly evaluated. Heart rate during the test was monitored by short range telemetry (using a Polar Vantage NV heart rate monitor) and downloaded onto the computer at a later date for analysis. Test-retest correlations of more than 0.85 have been reported when using this $\dot{V}O_2$ max assessment methodology (British Association of Sport Sciences, 1988).

4. 2. RESULTS

4. 2. 1. Physiological characteristics

The underlying physical characteristics, including age, weight, height and $\dot{V}O_2$ max, of the officials selected for the subject group are shown individually in Appendix B.

The ages of the officials' subject group showed a range between 25-47 years old, with a mean age of 38 years (s.d. +/- 7.1 years). The $\dot{V}O_2$ max results were in the range of 50.1 to 67.7 ml/kg/min, with a group mean of 55.8 ml/kg/min. (s.d. +/- 5.2 ml/kg/min).

4. 2. 2. Cardiovascular and blood lactate parameters

The oxygen uptake and heart rate values obtained from the laboratory assessments of maximum oxygen uptake and OBLA were correlated for each subject with the field measurements from the individual matches to ascertain the percentage of maximum oxygen uptake and maximum heart rate during the performance of refereeing and touch-judging duties. The results are summarised later in this chapter and detailed in full in Appendices E and G.

Relevant cardiovascular variables for the subject group collated at rest and during the maximal oxygen uptake test are displayed, along with the variables associated with OBLA, including values and percentages of estimated heart rate, maximal oxygen uptake and treadmill velocities obtained from the treadmill speed lactate test, in Appendices C (i) - (iii).

The range of resting lactate values ranged from 0.36 to 1.04 mmol/l with a group mean of 0.75 mmol/l (s.d. +/- 0.2 mmol/l). The maximal lactate values, recorded at the termination of the maximal oxygen uptake test, ranged from 6.74 mmol/l to 10.67 mmol/l with a group mean of 8.62 mmol/l (s.d. +/- 1.3 mmol/l).

The resting heart rates of the subjects group ranged from 49 beats/min to 75 beats/min, with a group mean of 63 beats/min. The maximal heart rate for the subjects group, recorded at the termination of the maximal oxygen uptake test, ranged from 169 beats/min to 199 beats/min with a group mean of 184 beats/min (s.d. +/- 11.1 beats/min). These results were compared to the subjects age predicted maximums, which had a range of 173 beats/min to 195 beats/min, with a group mean of 182 beats/min (s.d. +/- 7.1 beats/min).

The mean heart rate at OBLA for the subject group occurred at 160 beats/min (s.d +/- 6.82 beats/min) with a range of 150 to 172 beats/min.

4. 2. 3. Movement Analysis

4. 2. 3. 1. Total Distance Covered (metres) by referees' subject group

The total distances covered individually by the referees are summarised in Appendix D(i) and displayed in graphical format in figure 4.

The mean total distance covered by a referee during a level 1 and/or 2, eighty minute, match was 8086 metres (s.d. +/- 799 metres), with a range of 7036 metres to 9143 metres. Three of the ten subjects covered less distance in the second half than the first half and the remaining seven subjects covered more distance in the second half than the first. The mean difference between the two halves was found to be 23 metres which, using a repeated measures t-test, was found not to be statistically significant ($p=0.862$). The raw data for the t-test is detailed in Appendix O(ii). The mean of the ten matches observed showed that 50.1% (s.d. +/- 2.35%) of the total distance was covered in the first half and 49.9% (s.d. +/- 2.35%) in the second half. The figures summarising the individual percentages of total covered in each half are shown in Appendix D(ii).

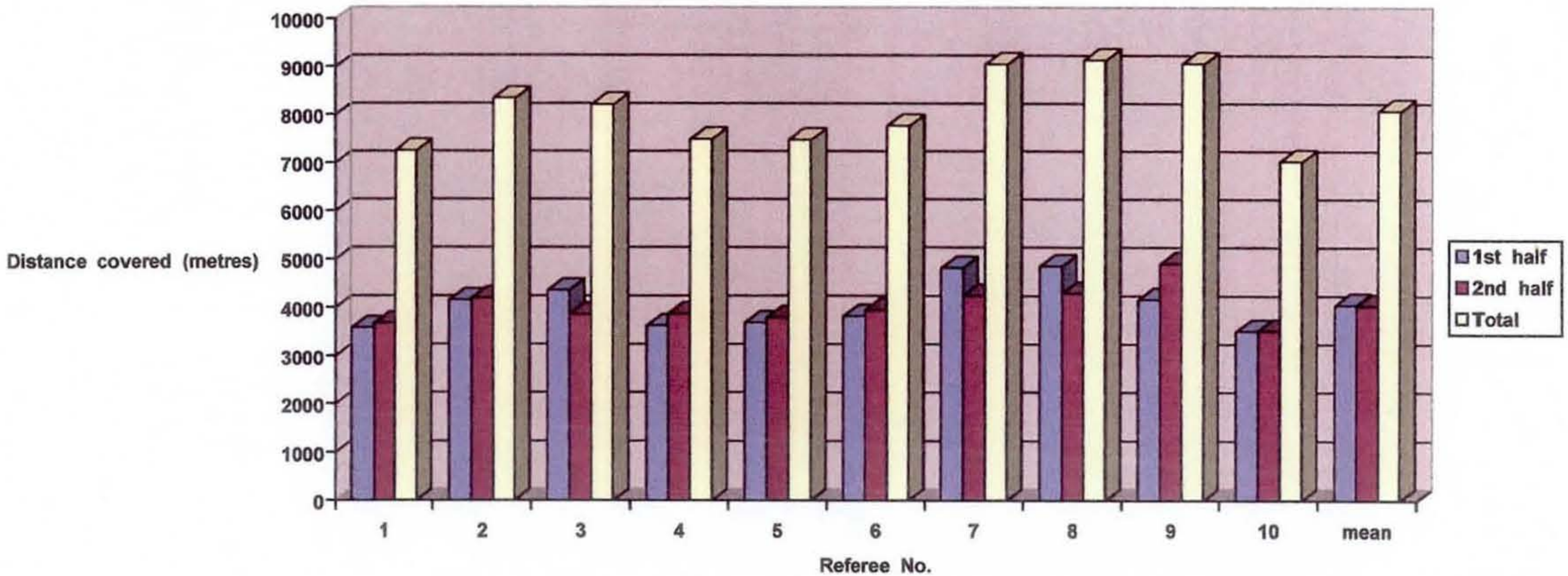


Figure 8 First half, second half and total distances covered by the referees during the matches analysed.

When comparing the total distance covered by referees in this study to the total distance covered by the referees' subject group in Spiller (1990), an increase from 4879 metres (s.d. +/- 847.1 metres) in the Spiller (1990) study to 8086 metres (s.d. +/- 799 metres) in this study was observed. The difference in total mean match distance covered was analysed statistically, using a t-test for independent samples, and was found to be statistically significant ($t=7.33$, $p<0.01$). The raw data for the t-test is detailed in Appendix O(iii).

4. 2. 3. 2. Total and average times and distances covered by the referees' subject group in different movement categories

The data relating to the distances travelled by the referees' subject group in the various movement categories, collected and analysed through video usage, is shown in summary format in tables XVI, XVII and XVIII. The raw data pertaining to each individual subject is shown in Appendix H.

A graphical interpretation of the percentages of the distance travelled and time spent in each of the various movement categories is illustrated in figures 5 and 6 following the tables.

Table XVI Summary of the total and mean distances and times covered in different movement categories by the referees' subject group for both halves combined

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	MEAN DISTANCE PER MOVEMENT SEGMENT (metres)	MEAN TIME PER MOVEMENT SEGMENT (seconds)	MEAN VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN MATCH (%)	PERCENTAGE OF TOTAL TIME SPENT IN MATCH (%)
Walking	405	1770	1058	4	3	1	21.9	21.8
Jogging	216	3840	1585	18	7	2	47.5	32.6
Running	57	1124	192	20	3	6	13.9	3.9
Sprinting	8	122	16	15	2	8	1.5	0.3
Walking (Back)	294	804	544	3	2	1	10.0	11.2
Jogging (Back)	36	133	44	4	1	3	1.7	0.9
Sideways	105	293	93	3	1	3	3.6	1.9
Standing	238	0	1331	0	6	0	0.0	27.4
TOTALS	1359	8086	4862	6	4	2	100	100

Table XVII Summary of the total and mean distances and times covered in different movement categories by the referees' subject group for the first half only

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	MEAN DISTANCE PER MOVEMENT SEGMENT (metres)	MEAN TIME PER MOVEMENT SEGMENT (seconds)	MEAN VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	202	843	503	4	2	2	20.8	20.6
Jogging	110	1982	820	18	7	2	48.9	33.5
Running	28	546	93	20	3	6	13.5	3.8
Sprinting	4	59	8	15	2	7	1.4	0.3
Walking (Back)	145	401	273	3	2	1	9.9	11.2
Jogging (Back)	19	73	24	4	1	3	1.8	1.0
Sideways	52	50	47	3	1	3	3.7	1.9
Standing	118	0	676	0	6	0	0.0	27.7
TOTALS	678	4055	2443	6	4	2	100	100

Table XVIII Summary of the total and mean distances and times covered in different movement categories by the referees' subject group for the second half only

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	MEAN DISTANCE PER MOVEMENT SEGMENT (metres)	MEAN TIME PER MOVEMENT SEGMENT (seconds)	MEAN VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	203	927	555	5	3	2	23.0	23.0
Jogging	106	1858	765	18	7	2	46.1	31.6
Running	29	577	99	20	3	6	14.3	4.1
Sprinting	4	63	8	16	2	8	1.6	0.3
Walking (Back)	149	403	271	3	2	1	10.0	11.2
Jogging (Back)	17	60	20	4	1	3	1.5	0.8
Sideways	53	143	46	3	1	3	3.5	1.9
Standing	120	0	655	0	5	0	0.0	27.1
TOTALS	681	4031	2419	6	4	2	100	100

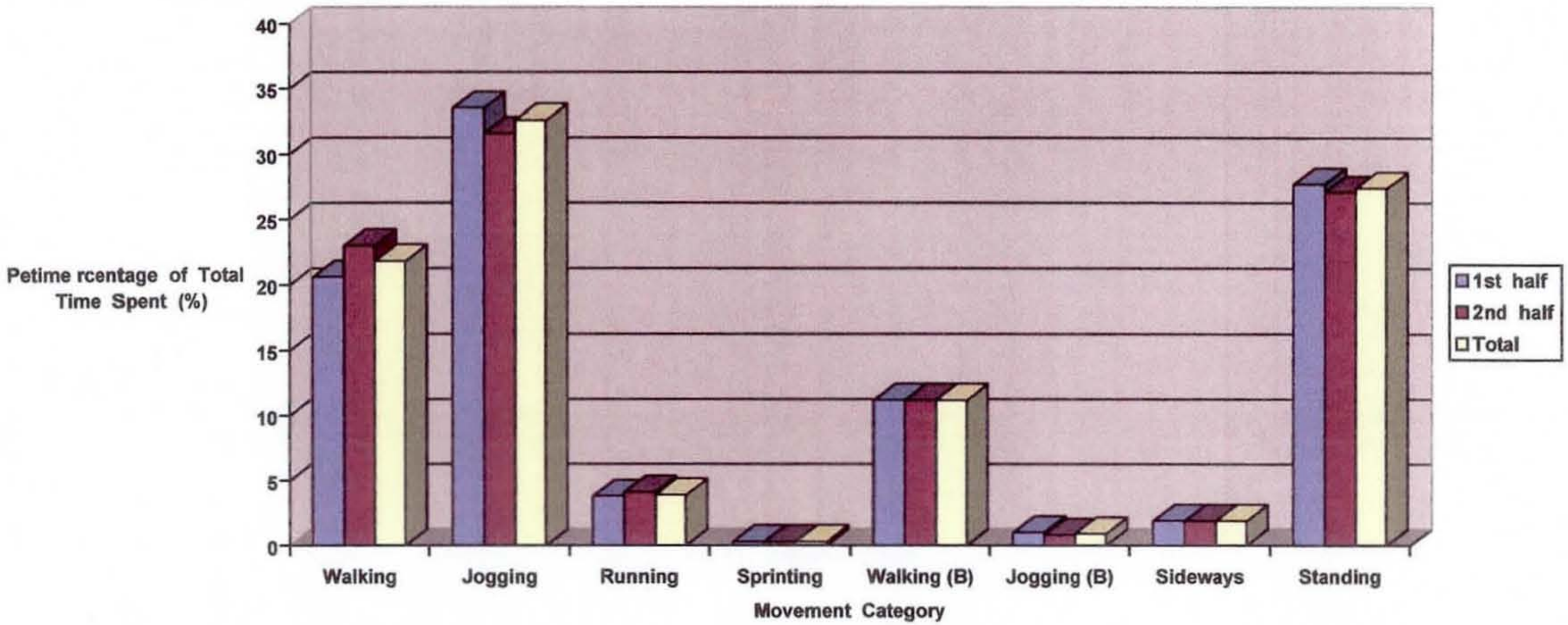


Figure 6 The percentage of total time spent in the different movement categories by the referees' subject group

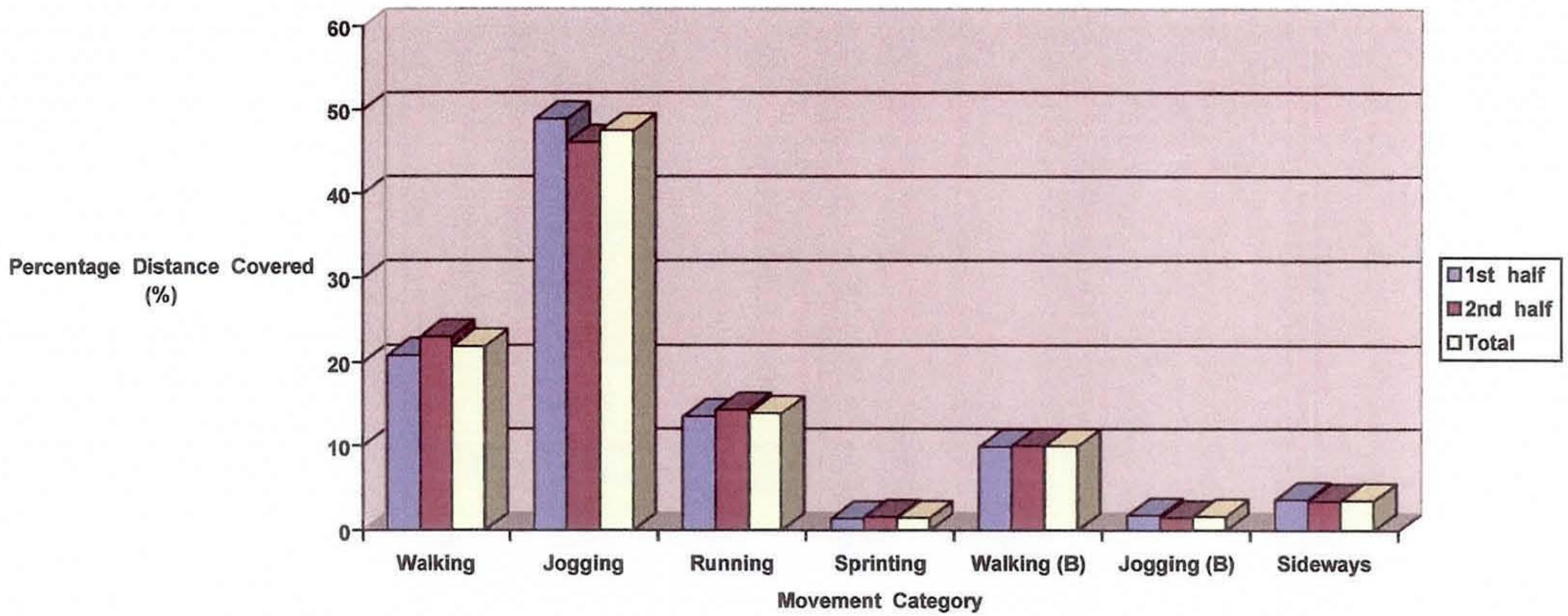


Figure 5 The percentage of total distance covered in the different movement categories by the referees' subject group

The results from this study indicate that the major categories of movement were walking, jogging and running with mean distances of 1770 (21.9% of the total distance), 3840 (47.5%) and 1124 (13.9%) metres respectively. The other categories of walking (backwards), jogging (backwards), sideways and sprinting showed means of 804 (10.0% of the total distance), 133 (1.7%), 293 (3.6%) and 122 (1.5%) metres respectively. The figures in brackets represent the percentage of total distance covered in the match by that movement category.

In terms of frequency of the individual movement categories, there were 1359 different movement segments within each game, with the majority of the time spent within the standing, walking and jogging categories. There were, as a mean, 405 walking passages of movement, 238 standing, 216 jogging and 294 walking (backwards). These categories contributed respectively 21.8%, 27.4%, 32.6% and 11.2% to the total time. Sprinting, jogging (backwards) and sideways categories of motion combined contributed only 3.1% to the total match time.

4. 2. 3. 3. Relationship of heart rate to movement analysis results

The heart rate variables for the referees' subject group, recorded during the matches through use of short range telemetry, are summarised in Appendix E.

Subject group means and standard deviations for a variety of cardiovascular measurements are shown. The raw data illustrating the entire heart rate trace and a subsequent breakdown of the data into various heart rate distributions for each referee is shown in Appendices J and L.

The mean heart rate of a referee during a level 1 and 2 match is 157 beats/min (s.d. +/- 7.55 beats/min) with a range of 144 to 167 beats/min. This figure is likely to be slightly higher during actual playing time, as the average recorded value includes half-time and injury time.

The mean heart rate as a percentage of the heart rate maximum of a referee averaged over the subject group at 86% (s.d. +/- 3.2%), with a range of 81 to 90%.

The range of heart rates recorded during the matches analysed averaged between 125 and 180 beats/min (s.d. +/- 19.2 beats/min and s.d. +/- 10.9 beats/min respectively), which equates to a range of 68 to 98% (s.d. +/- 10.2% and s.d. +/- 1.9% respectively) of the referee's maximum heart rate.

Finally the time spent above the heart rate, which correlates to the OBLA level, averaged for the whole subject group at 52.0% (s.d +/- 24.7%) of the total match. The range of results recorded lies between 10.9 to 84.3%.

4. 3. DISCUSSION

4. 3. 1. Introduction to the discussion topics

The initial focus of the discussion examines the implications of the findings on the hypotheses prescribed in chapter one. Based on the acceptance or rejection of these hypotheses, an analysis of current fitness testing protocols and recommendations for future testing procedures is outlined in chapter six.

4. 3. 2. Discussion of the subjects' basic physiological parameters

The subjects have a similar mean age to those in the Spiller (1990) study, thirty-eight as opposed to thirty-nine years of age, yet there was a small difference in the maximum oxygen uptake mean from 50.3 ml/kg/min to 55.8 ml/kg/min from the subjects in the Spiller (1990) study to those in this research.

Apart from the fact that the two samples involved different individuals, the difference in methodology for establishing $\dot{V}O_2$ max values could also contribute to this differential, as Spiller (1990) utilized the multistage fitness test, which has typically underestimated the $\dot{V}O_2$ max value when compared with results obtained by a standardised treadmill protocol in a laboratory.

Grant et al. (1995) showed that 'on average, the MST (multistage shuttle test) was 4.4 ml/kg/min lower than the treadmill $\dot{V}O_2$ max'.

When drawing comparisons to the basic physiological characteristics of officials within other codes of rugby, the recent HealthPac (1995) study showed an identical mean age and a lower mean $\dot{V}O_2$ max of 51.6 ml/kg/min. The methods for establishing maximal oxygen uptake were similar in this and the HealthPac (1995) study.

4. 3. 3. Discussion of the subjects' cardiovascular and blood lactate parameters

The mean recorded resting blood lactate value of 0.75 mmol/l, with a range of 0.36 to 1.04 mmol/l, is below that given by many researchers. Davis et al. (1997) state that 'the normal amount of lactic acid circulating in the blood is 1-2 mmol of lactic acid per litre of blood.' Reasons for this are unclear, although the subjects had been seated for a considerable amount of time prior to the testing, due to the quantity of travelling undertaken by many of the subjects and this may have been a factor responsible for the low lactate values.

The average maximal lactate value of 8.62 mmol/l, with a range of 6.74 to

10.67 mmol/l, is of interest when establishing the criteria for maximal oxygen uptake in adults. B.A.S.S. (1988) indicate that 'a post-exercise (4-5 minute) blood lactate concentration of 8 mmol/l' is desirable, indicating that the majority of subjects were approaching $\dot{V}O_2$ max on the final stage of the speed lactate test.

The mean resting heart rate of the subjects was recorded as 63 beats/min, with a range of 49 to 75 beats/min. Bowers and Fox (1992) report that 'usually, the heart beats between 60 and 80 times per minute in untrained men and women, but the rate is generally much lower (40 to 55 beats per minute) in trained athletes.' Wilmore and Costill (1994) support this and add that 'with extended periods of endurance training (months to years) the resting heart rate can decrease to 35 beats per minute or less.' The findings here show that six of the subjects have heart rates regarded as within the 'untrained' category, whilst the remaining four subjects have heart rates falling within the 'trained' category.

The maximal heart rates of the subjects ranged from 169 beats/min to 199 beats/min, with a mean of 184 beats/min. When comparing these results to the age predicted means (220-age), there can be seen to be discrepancies between the two sets of data with the magnitude of difference as great as 16 beats/min. This highlights the problems of using age-predicted maximums.

British Association of Sport Science (1988) state that 'a final heart rate of within 10 beats/min of the age-related maximum' is required for establishing maximal oxygen uptake and the results recorded here conform to these guidelines.

The mean heart rate at OBLA for the subject group occurred at 160 beats/min (s.d +/- 6.82 beats/min) with a range of 150 to 172 beats/min. Referring to Lamb (1984), who stated that the 4 mmol/l lactate level is 'detected at a heart rate of 170-190 beats/min', this can be seen to be a lower mean heart rate at the OBLA level than would be expected. However the reference population for Lamb's (1984) statement is unclear and it may possibly be that the subject group used in this study was atypical.

The estimated oxygen uptake at OBLA levels for the subject group occurred at a mean of 79.2% (s.d. +/- 5.7%) of $\dot{V}O_2$ max, with a range of 68.8% to 89.5%. This compares closely to the indicator of OBLA as quoted by Powers and Howley (1997), where the % $\dot{V}O_2$ max was between 60-95%, dependent on the subject group, with trained athletes having an OBLA level of 80-95% $\dot{V}O_2$ max.

4. 3. 4. Discussion of the movement analysis results

A number of points can be deduced from the results obtained for the referees and related to the referee-specific findings of Spiller (1990), Murray (1987) and HealthPac (1995). However it must be remembered that when drawing conclusions from this research that there has been only a small sample of data collected and errors may occur when generalising to the referees' population as a whole.

Firstly the physiological workload placed upon a referee at the top levels of the game, measured in distance travelled, should be examined in light of previous findings. A table illustrating the comparisons between the relevant research on rugby referees is shown in table XIX.

Table XIX Comparative analysis of total match distances covered by rugby referees

Source	Number of subjects (n)	Mean distance covered (metres)	Range of distance covered (metres)	Standard deviation (+/- metres)
Spiller (1990)	6	4879	3752 - 5509	847
Murray (1987)	6	8768	8080 - 9618	546
HealthPac (1995)	8	10293	7876 - 11970	1406
Current research	10	8086	7036 - 9143	799

The findings reported here illustrate that there has been a substantial increase from the average total distance recorded by Spiller (1990), 4879 metres (s.d. +/- 847 metres), to 8086 metres (s.d. +/- 799 metres) and that this difference, using a t-test for independent samples, is statistically significant ($t=7.33$, $p<0.01$). The raw statistical data is shown in Appendix O(iii). It would appear therefore that the results from this sample group indicate that there has been a significant increase in total match distance covered by referees over the past few seasons.

However a factor for discussion when considering that the workload has increased is the nature and style of the individual referee. Anecdotal observation of referees allows for the analysis of different techniques and it is possible to see individual differences occurring, which may affect the overall match distance covered. Some referees, through a combination of experience and style, will probably cover less distance than other referees would in the same game. This would be due to the more experienced referee having knowledge of better running angles, thus arriving at breakdowns in play with less physical effort and may also reflect a more relaxed and confident manner.

This point can be reinforced through the analysis of the matches in this research. If all referees' workload was independent of the individual referee's movement technique, then it would be anticipated that all referees would cover a larger distance in more open, high scoring matches than those where the play is more restricted. A comparison between the scores of the matches and the distance covered by the referees in this study was undertaken and a Pearson's product correlation test was applied to the data. It was found that there was no significant correlation between the scores of the matches, in terms of total number of points scored, and the total match distance covered by a referee ($r=0.213$, $p>0.10$). The raw statistical data is shown in Appendix O(iv).

Although this is a simplistic analysis it does give some support to the notion that the workload undertaken by a referee is affected by the individual style of the referee. However even by taking this into consideration, it still remains that there has been a significant increase in the referee's workload over the past few seasons.

It is also of interest to note that statistical comparisons with the data from this study and the research by Murray (1987) and HealthPac (1995), on rugby league referees, allows a contrast in the fitness demands on officials in both codes of rugby. The results of this study in terms of total distance covered were not different to the findings of Murray (1987), where the referees covered an average of 8768 metres (s.d. +/- 597 metres). (The raw statistical data is shown in Appendix O(v).) In contrast the findings of HealthPac (1995) showed that referees covered a significantly greater distance of 10293 metres (s.d. +/- 1503 metres). (The raw statistical data is shown in Appendix O(vi).)

The results of this study indicate that there is no significant difference in distance covered between the first and second halves of the matches recorded and this concurs with the data reported by Spiller (1990). One possible reason for this absence of difference between the halves is that the distance covered depended upon factors, such as players' strategies and attitudes, affecting the way in which the two separate halves are played. It appears from this evidence that fatigue is not influencing the results, as a significant reduction in distance covered would have been anticipated.

In terms of the total distances covered within the separate movement categories a degree of comparison can be undertaken between the results of this study and those of Spiller (1990). Table XX highlights the similarities and differences between the two studies.

Table XX Comparison of total distances covered and the relative percentages of each movement category

	SPILLER (1990)		CURRENT RESEARCH	
MOVEMENT PATTERN	TOTAL DISTANCE COVERED (metres)	PERCENTAGE OF TOTAL DISTANCE COVERED (%)	TOTAL DISTANCE COVERED (metres)	PERCENTAGE OF TOTAL DISTANCE COVERED (%)
Walking	1147	23.2	1770	21.9
Jogging	2380	49.2	3840	47.5
Running	545	10.7	1124	13.9
Sprinting	25	0.6	122	1.5
Walking (Back)	544	11.2	804	10.0
Jogging (Back)	70	1.5	133	1.7
Sideways	190	3.7	293	3.6

The total distances covered in a match in all of the categories of movement have shown marked increases from the work of Spiller (1990), but many of the percentage contributions to total distance covered by each movement category have remained similar. This would tend to indicate that although the actual game has increased in its physical demands, the nature of the game has remained constant.

When comparisons are drawn with findings in other codes of Football, it can be seen that the referees in this study were covering similar distances to those reported by players in Association Football, where Reilly (1986) indicated a range of 8-12 kilometres for outfield players, recorded from various research. Also the calculations from this study show similar total distances recorded for players in Rugby Union, where the results range from 3.8 to 9.6 kilometres (Reid and Williams, 1974; Williams; 1976; Morton 1978 and Deutsch et al., 1998)

A category of movement not examined by Spiller (1990) was that of standing, which appears to occupy, on average, about 27% of referees' match time, with a frequency of 238 separate incidences. There are no recorded studies covering officiating in either code of rugby which allow empirical evaluation and comparison of this data.

Another area of contrast between this and Spiller's (1990) study is that of the number of repetitions and average distance for each movement category within a match. The total frequency of movement repetitions has become greater, with the reported mean of 495 having increased to 1121 (removing standing repetitions from the data from this study to allow equity), a 126.5% increase.

In contrast, the mean distance covered by a single repetition has decreased, with Spiller (1990) recording a mean distance of 9.88 metres per repetition whilst this study showed a mean of 7 metres per repetition (with standing removed). This would indicate that although the frequency of movement has increased, with a corresponding increase in distance covered, the referees are making more rapid changes in speed and direction than was previously the case. This is highlighted particularly in the categories of walking forward and backwards, where the mean distance per movement segment has shown a reduction from 7.5 metres to 4 metres (forwards) and 4.3 metres to 3 metres (backwards).

These results show that, whilst the demands on referees in the code of Rugby Union appear to have increased substantially over the past eight years, the officials are not currently having to match the physical workload of the referees in the code of Rugby League, although the present demands are highly similar to those placed on Rugby League officials ten seasons ago.

When examining the data on the quantity of high intensity work undertaken by a referee at the top levels of the game, measured in distance covered at speeds above jogging levels, it can again be compared to the levels recorded by Spiller (1990). Analysis of the high intensity workload (running and sprinting) reveals that in this study a referee covered 1124 metres (13.9% of total distance, 3.9% of total time) in the running category and 122 metres (1.5% of total distance, 0.3% of total time) in the sprinting category as a mean. Spiller (1990) records figures of 544.50 metres of running (10.67% of total distance) and 24.86 metres of sprinting (0.6% of total distance).

Statistical analysis of the two studies in the high-intensity classification of movement, showed a significant difference ($t=5.13$, $p<0.05$), with an increase of 127.6% in total distance travelled. (The raw data for the t-test is detailed in Appendix O(vii).) Therefore there appears to have been a significant increase in the quantity of high intensity work performed, in terms of total match distance, by referees since the study by Spiller (1990). This is reinforced by a statistically significant increase in the quantity of high intensity work, in terms of percentage of total match distance covered, undertaken by a referee since the study by Spiller (1990). (The raw statistical data is shown in Appendix O(viii).)

In the event of an increase in high intensity work undertaken by a referee, fitness testing procedures should look to assess anaerobic, as well as aerobic, performance. Clearly the evidence presented above provides a substantial argument for the fitness testing procedures to be reviewed in the light of a significant increase in the quantity of total distance covered in the high-intensity categories of movement.

What is not clear from this data alone is whether the category of high-intensity activity is utilizing the anaerobic energy pathways for all subjects and, therefore, all referees involved in the game of rugby union. Certainly there will be referees with high OBLA levels, where the speed of the running activity will need to be at its highest to generate a requirement for anaerobic metabolism. Conversely there may be situations where referees with a low OBLA level will have an need for anaerobic metabolism at the higher end of the jogging category.

In addition, although there has been a significant increase in the total distance covered within the high-intensity categories of movement, the total match distance in these two categories is still relatively small. As highlighted previously, the referee covers, on average, 1124 metres in the running category (13.9% of the total match distance) and 122 metres in the sprinting category (1.5% of the total match distance). This amount, totalling an average of 15.4% of the total match distance, implies that it would be difficult to justify the inclusion of tests to examine anaerobic energy provision based on distance covered alone.

4. 3. 5. Discussion of the match-based heart rate results

Significant evidence is raised in support of the use of tests in which energy is supplied mainly from anaerobic pathways by the findings of the heart rate data during the matches analysed. The mean heart rate as a percentage of the heart rate maximum of a referee averages over the subject group at 86%, with a range of 81 to 90%. Using a HR-$\dot{V}O_2$ correlation graph this would result in an estimation of around 75% $\dot{V}O_2$ max on average, with a range of approximately 70 to 80% of $\dot{V}O_2$ max, indicating a substantial load being placed on the referee.

The figures are comparable to those elicited by Murray (1987), where 'on average a referee is working at 91% of the maximum heart rate during the entire game.' The range varies from 83 to 96%, which again is a marginal increase on the results recorded herein. The HealthPac (1995) study reports a mean heart rate from Rugby League referees of 86%, a highly similar figure to that found in this study.

The range of heart rates recorded during the matches analysed were between 125 and 180 beats, which equates to a range of 68 to 98% of the referee's maximum heart rate. HealthPac (1995) reported a range of 119 to 175 beats/min which corresponded to a mean of 65 to 96% during the entire game.

Finally the time spent above the heart rate, which correlates to the OBLA threshold, was recorded as a mean of 52.0% of the total match. The range of results recorded lies between 10.9 to 84.3%. This, coupled with the fact that the mean heart rate in a match is 86% of the referees' maximum, with a mean range of 68-98%, lends credence to the idea that the fitness testing procedures should be re-evaluated, with a view to testing the efficiency of the anaerobic metabolic pathways, alongside aerobic performance. This area of discussion is examined further in chapter six.

The data from this research has illustrated the substantial increase in physical work that a referee undertakes in the elite spheres of the sport of rugby union. With an increase of average total match distance from 4878 metres to 8086 metres and the average heart rate in a match being 157 beats/min or 86% of a referee's maximum, the data points to the rejection of the belief that the quantity, quality, and type of fitness training that a referee has to undertake at the top level has not changed from the recommendations of Spiller (1990).

Due to the increased loading from aerobic metabolism placed on an official, the referee's maximum oxygen uptake levels need to be improved. Reilly (1996) highlighted the need for increased levels of endurance capacity by stating that 'the high level of exercise intensity associated with refereeing has consequences both for mental judgements and for fitness. Decrements in cognitive function are noted once the exercise intensity exceeds about 50% $\dot{V}O_2$ max'.

Alongside of this issue is the fact that not only must an official be capable of completing the increased distance at the pace required but there must be no decrease in the overall efficiency of the official's decision-making processes in the later stages of a match. Again Reilly (1996) reports that 'a fatigue effect is evident in referees as indicated by a fall-off in work-rate towards the end of play' and that 'the fatigue is linked with diminishing energy stores within the active muscles.'

This has implications for both the dietary requirements of the official and the quality and quantity of endurance conditioning that an official undertakes as part of an overall fitness programme.

It appears that the quantity of work utilising the aerobic pathways of energy creation has increased and there is also a significant anaerobic energy provision demand by the referee within a match. This is supported by the time spent above a heart rate indicative of OBLA levels, where on average 52% of total match time is above this level. This evidence points to the need for referees to improve not only $\dot{V}O_2$ max levels as far as is physically possible, but also to focus upon the improvement of the individual OBLA level. This would enable referees to perform the demands of a match with a reduction in the physical stress, there would be a decrease in time spent above OBLA levels and also an associated reduction in lactate concentrations.

This would appear to contradict the statement by Williams (1996) who states that 'one can question the value of increasing a player's 'anaerobic threshold'' and that 'recent research suggests that it is the $\dot{V}O_2$ max, not the anaerobic threshold, that is the most important aspect of aerobic fitness for rugby players.'

However the recent findings by Deutsch et al (1998) where the results indicated that 'props and back row forwards may spend up to 20% of match time above 95% of maximum competitive heart rate' and mean blood lactate concentrations ranging from 4.7 to 7.2 mmol/l for outside backs and back row forwards were recorded, would indicate a 'considerable contribution from anaerobic glycolysis.'

Certainly the results from mean heart rate in this study and the results from Deutsch et al (1998) and McLean (1992), would appear to indicate 'a need for 'lactate tolerance' training to improve intra-muscular buffering capacity and lactate metabolism.' (Deutsch et al, 1998).

In summary it is possible to draw conclusions for future fitness training. The mean match distance of 8086 metres, a mean heart rate of 157 beats/min and the mean time spent above the OBLA level being 52.0% of total match time, a balance of endurance training, to increase the referee's $\dot{V}O_2$ max and improve recovery between repeated bouts of high intensity activity, and speed conditioning, to elevate the official's lactate threshold, would be the recommendation from this research. The quality and type of training that a referee undertakes for match preparation must therefore be reviewed in the light of the recent evidence.

CHAPTER 5

MATCH AND LABORATORY ANALYSIS OF TOUCH-JUDGES

5. 1. METHODOLOGY

5. 1. 1. Introduction

The study aimed to examine the physiological demands placed on touch-judges, whilst performing their duties during a high level match of rugby union.

The testing of the touch-judges, as for the referees' subject group, involved the recording in the game of all movement patterns and the associated physiological variables, i.e. heart rate, elicited by one level 1 and/or 2 match. The results from the field measurements were correlated with a range of laboratory test results to assess the relative physiological stress placed on each official.

The subjects for this section of the study were those identified in chapter four. All the laboratory, match and statistical analysis conducted was identical to that performed by the referees, detailed in the previous chapter.

5. 2. RESULTS

5. 2. 1. Basic physiological parameters

The physical characteristics, including age, weight, height and $\dot{V}O_2$ max, of the officials have been summarised in chapter four and outlined fully in table format in Appendix B, with the cardiovascular and blood lactate parameters outlined in Appendix C. The results of the movement analysis are detailed below.

5. 2. 2. Movement Analysis

5. 2. 2. 1. Total Distance Covered (metres) by touch-judges' subject group

The total distances covered by the touch-judges in the matches that were filmed are summarised in Appendix F(i) and illustrated in graphical format in figure 7.

Figure 7 First half, second half and total match distances covered by the touch-judges', during the matches analysed.

The mean total distance covered by a touch-judge during a level 1 or 2, eighty minute, match was 4906 metres (s.d. +/- 666 metres), with range of 3985 metres to 6409 metres. Five of the ten subjects covered less distance in the second half than the first half and the remaining five subjects covered more distance in the second half than the first. The mean difference in distance covered, between the two halves, was found to be 157 metres which, was found not to be statistically significant (p=0.248). The raw data for the t-test is detailed in Appendix O(ix).

The mean of the ten matches observed showed that 51.5% (s.d. +/- 4.02%) of the total distance was covered in the first half and 48.5% (s.d. +/- 4.02%) in the second half. The figures for each individual subject illustrating this are shown in Appendix F(ii).

The mean total distance covered by touch-judges in this research was 4906 metres (s.d +/- 666), which, when compared with 5683.50 (s.d +/- 255.27) metres found by Murray (1987), revealed no significant difference when analysed using an independent samples t-test (t=-1.58, p=1.46). The raw data for the t-test is detailed in Appendix O(x).

Another comparison of relevance is that between this study and the mean total distance findings from Spiller (1990). The two sets of data were analysed using a t-test for independent samples and there was found to be no significant difference ($t=.07$, $p=0.946$). The raw data for the t-test is detailed in Appendix O(xi).

5. 2. 2. 2. Total and mean times and distances covered by the touch-judges' subject group in different movement categories

The data relating to the distances travelled by the touch-judges' subject group in the various movement categories, collected and analysed through video usage, is shown in summary format in tables XXI, XXII and XXIII. The raw data pertaining to each individual subject is shown in Appendix I.

A graphical interpretation of the percentages of the distance travelled and time spent in each of the various movement categories is illustrated in figures 8 and 9 following the tables.

Table XXI Summary of the total and mean distances and times covered in different movement categories by the touch judges' subject group for both halves combined

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	MEAN DISTANCE PER MOVEMENT SEGMENT (metres)	MEAN TIME PER MOVEMENT SEGMENT (seconds)	MEAN VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN MATCH (%)	PERCENTAGE OF TOTAL TIME SPENT IN MATCH (%)
Walking	344	1663	1122	5	3	1	33.9	23.3
Jogging	120	2217	935	18	8	2	45.2	19.4
Running	20	394	69	20	3	6	8.0	1.4
Sprinting	3	58	8	19	3	7	1.2	0.2
Walking (Back)	161	302	249	2	2	1	6.2	5.2
Jogging (Back)	14	68	27	5	2	3	1.4	0.6
Sideways	64	204	69	3	1	3	4.1	1.4
Standing	240	0	2330	0	10	0	0.0	48.5
TOTALS	966	4906	4809	5	5	1	100	100

Table XXII Summary of the total and mean distances and times covered in different movement categories by the touch judges' subject group for the first half only

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	MEAN DISTANCE PER MOVEMENT SEGMENT (metres)	MEAN TIME PER MOVEMENT SEGMENT (seconds)	MEAN VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	172	815	534	5	3	2	32.2	22.1
Jogging	63	1173	485	19	8	2	46.3	20.1
Running	10	212	38	21	4	6	8.4	1.6
Sprinting	1	24	3.4	24	3	7	1.0	0.1
Walking (Back)	85	164	135	2	2	1	6.5	5.6
Jogging (Back)	6	33	13	6	2	3	1.3	0.5
Sideways	35	110	43	3	1	3	4.3	1.8
Standing	120	0	1163	0	10	0	0.0	48.2
TOTALS	492	2531	2414	5	5	1	100	100

Table XXIII Summary of the total and mean distances and times covered in different movement categories by the touch judges' subject group for the second half only

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	MEAN DISTANCE PER MOVEMENT SEGMENT (metres)	MEAN TIME PER MOVEMENT SEGMENT (seconds)	MEAN VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	172	849	588	5	3	1	35.7	24.6
Jogging	57	1044	450	18	8	2	44.0	18.8
Running	10	182	31	18	3	6	7.7	1.3
Sprinting	2	34	4.6	17	2	7	1.4	0.2
Walking (Back)	76	138	114	2	2	1	5.8	4.8
Jogging (Back)	8	35	14	4	2	3	1.5	0.6
Sideways	29	94	26	3	1	4	3.9	1.1
Standing	120	0	1167	0	10	0	0.0	48.7
TOTALS	474	2375	2395	5	5	1	100	100

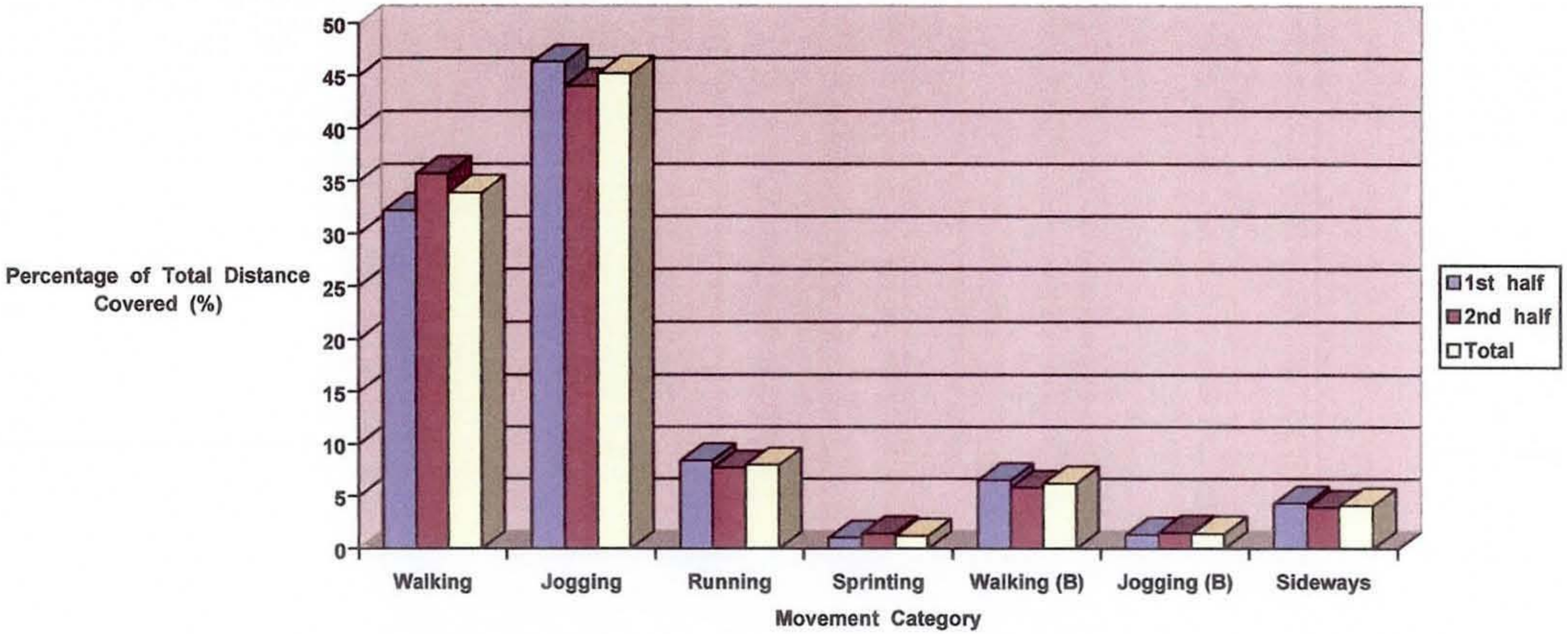


Figure 8 The percentage of total distance covered in the different movement categories by the touch-judges' subject group

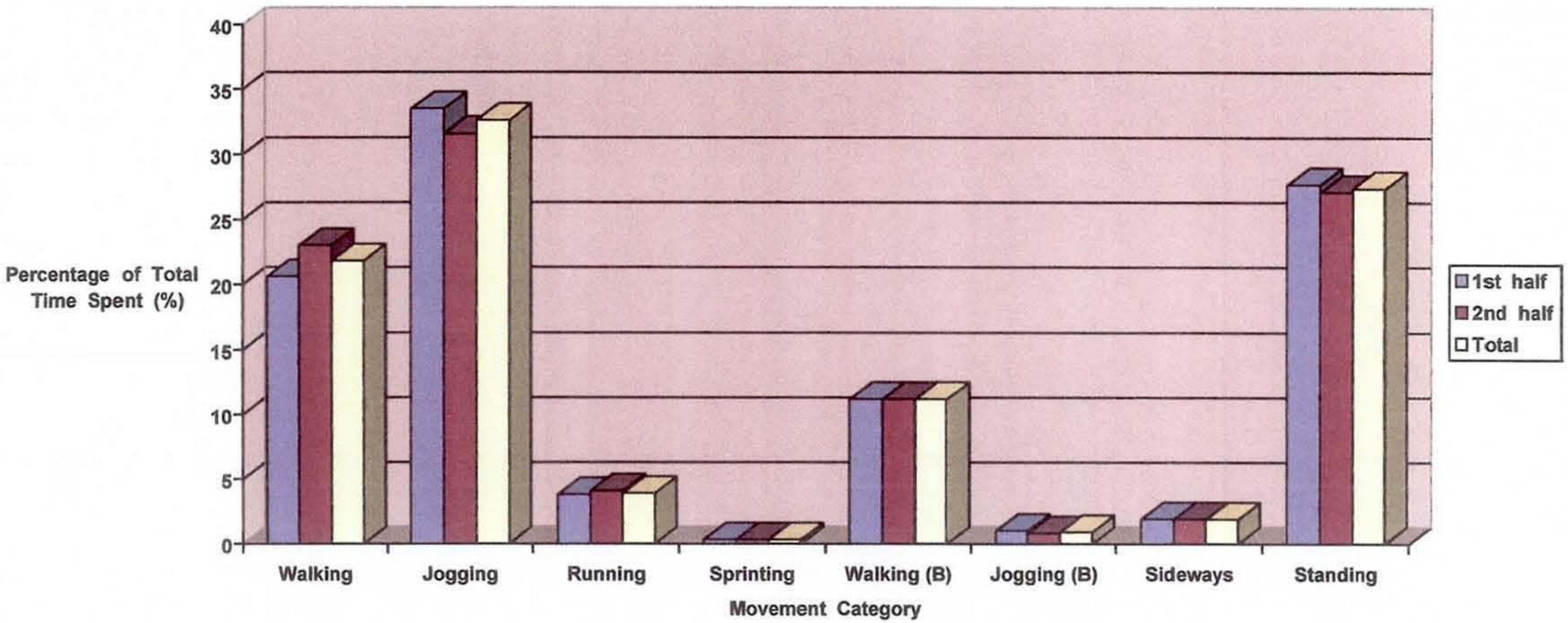


Figure 9 The percentage of total time spent in the different movement categories by the touch-judges' subject group

The results from this study indicated that the major categories of movement were walking, jogging and running with mean distances of 1663 (33.9%), 2217 (45.2%) and 394 (8%) metres respectively covered by the touch-judges. The other categories of walking (backwards), jogging (backwards), sideways and sprinting showed means of 302 (6.2%), 68 (1.4%), 204 (4.1%) and 58 (1.2%) metres respectively. The figures in brackets represent the percentage of total distance covered in the match by that movement category.

In terms of frequency of the individual movement categories, there were on average 966 different movement segments within each game, with the majority of the time spent within the standing, walking and jogging categories. There were, as a mean, 344 walking passages of movement, 240 standing, 120 jogging and 161 walking (backwards). These categories contributed respectively 23.3%, 48.5%, 19.4% and 5.2% to the total time spent in the match by the touch-judge. Sprinting, jogging (backwards) and sideways categories of motion combined contributed, on average, only 2.2% of the total match time.

5. 2. 2. 3. Relationship of heart rate to movement analysis results

The heart rate variables for the touch-judges' subject group, recorded during the matches through use of short range telemetry, are detailed individually in

Appendix G. Subject group means and standard deviations for a variety of cardiovascular measurements are shown. The raw data illustrating the entire heart rate trace and a subsequent breakdown of the data into various heart rate distributions for each touch-judge is shown in Appendices K and M.

The mean heart rate of a touch-judge during a level 1/2 match is 108 beats/min (s.d +/- 12.5 beats/min) with a range of 88 to 126 beats/min. As discussed in the previous chapter this figure is likely to be slightly higher during actual playing time, as the mean recorded value includes half-time and injury time.

The mean heart rate as a percentage of the heart rate maximum of a touch-judge averages over the subject group at 59% (s.d. +/- 6.41%), with a range of 48 to 68%.

The range of heart rates recorded during the matches analysed averages between 74 and 150 beats, which equates to a range of 40 to 82% of the referee's maximum heart rate.

Finally the time spent above the heart rate, which correlates to the OBLA threshold of 4 mmol/l determined through the laboratory testing, averaged for the whole subject group at 0.1% (s.d +/- 0.21%) of the total match. This means that the touch-judge, on average, is spending only 5 seconds above the heart rate indicative of the 4 mmol/l OBLA level. The range of results recorded lies between 0 to 0.5% (0 to 25 seconds per match.)

5. 3. DISCUSSION

5. 3. 1. Discussion of the movement analysis results

The two important factors to be considered when discussing the movement analysis results are firstly whether a significant work demand is placed on the touch-judges and, secondly, whether the fitness testing and training programmes of the RFU panel of touch judges have a need to be re-evaluated and increased in their intensity.

The data from this study showed that the mean total distance covered by a touch-judge during a level 1 and/or 2, eighty minute, match was 4906 metres, with a range of 3985 metres to 6409 metres. Due to the relative lack of studies carried out on the physiological demands placed on touch-judges in the codes of rugby, there are limitations on the number of empirical comparisons that can be made with other research.

However the study by Murray (1987) can be used as a benchmark for future recommendations, although the small sample size used in the research by Murray (1987) must be borne in mind, as this reduces the validity and reliability of the findings. The mean total distance covered by touch-judges in this research, amounting to 4906 metres, when compared with that found by

Murray (1987), totalling 5683 metres, revealed no significant difference and this would allow similar recommendations to be used for both sets of data.

Another comparison of relevance is that between this study and the findings from Spiller (1990). The touch-judges in the modern game, as highlighted earlier in the study, have had their roles and responsibilities redefined over the last few seasons and therefore there is an interest to be taken in examining the results of distances covered by a touch-judge in this study and that of the referees eight years previously. There was found to be no significant difference between the two sets of data and would also allow similar recommendations for both groups.

When analysing the similarities between the data reported here and the results of Murray (1987) and Spiller (1990) the distances covered by subjects within the different movement categories is of relevance. The distance covered by touch-judges in a match in the categories of walking, jogging or running, in both forwards and backwards directions, is, as a mean, 95% of the total distance covered. This is closely related to the findings for referees of Spiller (1990) and this study and also Murray (1987) highlighted that rugby league touch-judges covered 94% of the total match distance in this manner.

The largest discrepancy when drawing comparisons to the research by Murray (1987) is that of the distance covered by jogging and running. Murray (1987) reports that touch-judges, as a mean, cover 1237 metres (21.8% of total distance) in contrast to 2217 metres (45.2% of total distance) through jogging and that 2326 metres (40.9%) in contrast to 394 metres (8.0%) is covered through running. This large discrepancy could be explained by the fact that the definitions of jogging and running may differ between the two studies, but Murray (1987) does not define the movement categories sufficiently to allow closer examination of this potential variation.

The comparison with the data from the referees in the study by Spiller (1990) reveals close agreement in a number of movement categories. Walking, jogging and running by the referees in Spiller's (1990) study results in total match distances of 1147, 2379 and 544 metres, respectively, which are closely matched by the touch-judges in this study, where mean distances of 1663, 2216 and 394 metres, respectively were covered in the three movement classifications. The only category showing a large discrepancy is that of walking (backwards), which showed a mean of 543 metres (for referees) and 301 metres (for touch-judges).

The movement categories of walking (backwards) and jogging (backwards) illustrate differences, as Murray reports only 140 metres (2.5% of total distance) travelled by touch-judges walking (backwards) and 0 metres travelled running backwards. This is substantially less than the 302 metres (6.2%)

covered by walking (backwards) and 68 metres (1.4%) covered by jogging (backwards) in this study.

These results would appear to indicate that touch-judge fitness programmes have a need to focus upon the development of maximal oxygen uptake, to enable the substantial workload of a touch-judge to be undertaken without affecting the decision-making processes of the official, particularly in the later stages of a match. Likewise future testing protocols should focus upon the endurance capacity of touch-judges, to ensure match distances can be adequately covered without undue stress.

5. 3. 3. Discussion of the match-based heart rate results

The mean heart rate during the matches analysed was 108 beats/min and when calculated as a percentage of the heart rate maximum of a touch-judge the subject group mean was 59%, with a range of 48 to 68%. The figures show a differential to those elicited by the Murray (1987) subject group, where 'on average they (touch-judges) are working at 78% of the maximum heart rate during the entire game.' The range varies from 69 to 87%, which again is an increase on the results recorded herein.

The statement by Reilly (1996) that 'the high level of exercise intensity associated with refereeing has consequences both for mental judgements and for fitness' is pertinent for touch-judges as there will be a fatigue effect evident due to the distances covered and the relative intensity of the matchplay. Also as the average exercise intensity is around 50% $\dot{V}O_2$ max there will be associated 'decrements in cognitive function' (Reilly, 1996), which an improved cardiovascular fitness will help to allay.

In comparison the high intensity workload appears to be relatively small, with only 0.1% of the match time spent above a heart rate indicative of OBLA levels and the high-intensity categories of movement contributing only 394 metres of running distance and 58 metres of sprinting distance, equating to 8.0% and 1.2% of total match distance respectively. This would seem to indicate that the fitness training and testing programmes for touch-judges have little need to focus upon developing anaerobic metabolism or power output.

In summary it would appear, therefore, from these findings that there is no significant workload placed on the touch-judges that require anaerobic energy provision and that fitness testing and training programmes should focus on maximal oxygen uptake measures. Further discussion of relevant fitness testing of touch-judges is covered in chapter six.

CHAPTER 6

FITNESS TESTING

6. 1. Fitness testing for officials - introduction

The relevance and merits of the current fitness testing methods have been questioned repeatedly during recent times. The necessity of the fitness testing process has been debated, along with the validity of the aerobic parameters that were established, based upon the original work of Spiller (1990). There has also been concern expressed by individuals involved in the testing procedure that there may be undue risks being placed on the officials, particularly in the incidence of lower limb injuries caused by the multistage fitness test and the cardiovascular loading that a test of this nature places on mature subjects.

When examining the findings and the related hypotheses, as discussed in chapter four, it is obvious that the argument in favour of fitness testing for rugby union referees is a strong one. With the total distance covered by referees apparently having significantly increased in the past eight seasons, from a mean of approximately 5000 metres to approximately 8000 metres, the justification for fitness standards to improve is unequivocal.

Alongside this fact is the workload of touch-judges is now substantial, with the mean distance of approximately 5000 metres being covered, a distance that correlates closely to that found by Spiller (1990) for the referees sample. As discussed previously the fitness testing procedures and standards for touch-judges should also be re-evaluated in light of this evidence and increased in their rigour.

Traditionally the fitness testing protocols for referees have included a variety of measures for a number of fitness characteristics. The benchmark test adopted by the Rugby Football Union in the early stages of fitness testing was the multi-stage fitness test, a maximal field test measuring aerobic capacity.

This test uses a progressive method for assessing $\dot{V}O_2$ max, where individuals are asked to run continually between two sets of cones, 20 metres apart, to the sound of a tape recorded pacer. As the test progresses, the intensity of the exercise is increased every minute, with the time allowable between the two sets of cones decreasing gradually. When an individual can no longer maintain the set pace, they are removed from the test and the level reached is used as an predicted indication of the individual's $\dot{V}O_2$ max. The Rugby Football Union adopted a level 10, shuttle 4 standard (equating to a $\dot{V}O_2$ max value of 48.4 ml/kg/min) over the recent seasons as an indication of the referee's match fitness and raised this standard to level 11, shuttle 5 in the 1998/99 season.

Alongside this test, there have been flexibility, particularly focusing on lower body range of movement, speed (15 and 30 metres) and body composition (skinfold) measures of fitness, but none of these have been used to establish a referee's readiness to officiate. Guidelines have been offered to officials about the various results. Recently these supplementary tests have been abandoned, with the solitary measure of maximal oxygen uptake being retained as a benchmark of the officials' fitness levels.

Touch-judges have only had a field test focusing on anaerobic metabolism to undertake until the 1997/98 season, where the individuals were asked to perform repeated shuttle sprints with a short rest period in between each repetition. There were no standards adopted, but the results were fedback to the individual for purposes of monitoring current states of fitness. Since the 1997/98 season, however, the RFU have adopted the Cooper 12 minute endurance performance test as the standard for touch-judges, with a benchmark of 2400 metres being set for the 1998/99 season.

There is, however, now a justification for questioning and adapting the current testing procedure to reflect more closely the rigours that are placed on the physiological systems of the referee and touch-judges. The specificity and validity of the fitness procedures used in the past are open to question in light of the evidence brought forward. Bangsbo (1992) questions 'whether maximum oxygen uptake or blood lactate can be used to evaluate intermittent exercise endurance capacity and physical performance' within Association Football, a game with similar characteristics to that of Rugby Union.

In addition Bangsbo (1992) points out that '$\dot{V}O_2$ max does not seem to be an accurate measure of the soccer-specific endurance capacity. This is in agreement with earlier findings in soccer and other sports. Thus, in studies of endurance-trained cyclists with similar maximum oxygen uptakes, a great variation in endurance capacity for continuous exercise was observed.'

In assessing whether maximal oxygen uptake is a solid gauge of performance within an intermittent-type game, it is of relevance to consider the data collated by this study. If $\dot{V}O_2$ max were an accurate indicator of endurance capacity and related to the ability of a referee to sustain the workload demanded by a match, then it would be reasonable to anticipate a significant correlation existing between $\dot{V}O_2$ max and total distance recorded within the matches by a referee. This would also be a relevant statement when performing the role of a touch-judge. In addition to this hypothesis it is of interest to examine the relationship between the $\dot{V}O_{2OBLA}$ values and the total distance covered by the subject group, in both the refereeing and touch-judging capacities. The relationship between these variables is shown in table XXIV.

Table XXIV Total distances covered by the subject group as referees and touch-judges in the matches recorded and the relationship to physiological variables

SUBJECT	TOTAL DISTANCE – REFEREE (metres)	TOTAL DISTANCE - TOUCH-JUDGE (metres)	$\dot{V}O_2$ max (ml/kg/min)	$\dot{V}O_{2OBLA}$ (ml/kg/min)
1	7252	4756	54.7	49.0
2	8345	3985	50.9	35.0
3	8213	5140	55.6	45.0
4	7491	4447	59.7	43.0
5	7478	4487	51.4	39.0
6	7767	5042	56.5	46.0
7	9058	6409	57.4	45.0
8	9143	5281	67.7	55.0
9	9073	5084	50.1	41.0
10	7036	4429	54.4	44.0
MEAN	8086	4906	55.8	44.2
S.D.	799	666	5.2	5.45

6. 1. 1. Statistics

The correlations between distance covered as a referee and as a touch-judge and the physiological variables of $\dot{V}O_2$ max and $\dot{V}O_{2OBLA}$ were performed using a Pearson's product correlation test and the raw data can be found in Appendix O(xii).

This test was selected on the bases that the data was of a parametric (ratio) nature and the relationship between two variables was being assessed, i.e. the extent to which the size and direction of the deviations from the mean in one variable (the first measurement) are related to the size and direction from the mean in the second variable (the second measurement). To ensure statistical rigour a 99% level of confidence was applied to the test ($p<0.01$).

The definition formula for Pearson's product moment correlation coefficient (r) is :

$$r = \frac{\Sigma[(Zx)(Zy)]}{N}$$

where: Zx and Zy are the Z scores for each subject on the X and Y variables

N is the number of pairs of scores

It was discovered that in all cases a poor correlation existed between the match distances and the physiological variables. The correlation between the total distance covered by the referees' subject group and $\dot{V}O_2$ max/$\dot{V}O_{2OBLA}$ was 0.26 and 0.16 ($p>0.05$ in both cases) respectively, indicating that maximal oxygen uptake and OBLA levels were not good indicators of workload during a match. This finding was replicated by the correlation between the total distance covered by the touch-judges' subject group and $\dot{V}O_2$ max/$\dot{V}O_{2OBLA}$, where correlation values of 0.37 and 0.48 ($p>0.05$ in both cases) respectively were recorded.

From this evidence and that presented by other researchers, e.g. Bangsbo (1992) it would appear that maximal oxygen uptake alone is not a good indicator of ability to perform rugby-specific work and it is highly desirable, therefore to look to develop a rugby-specific endurance capacity test for officials.

In assessing the current endurance capacity tests, traditionally officials, in general, and referees, in particular, have had fitness levels assessed through widespread use of the multistage fitness test. Whilst the multistage fitness test has been accepted for sometime as an accurate and reliable testing tool to predict $\dot{V}O_2$ max values (Leger and Lambert, 1982), there are question marks over whether this test truly reflects the physiological stress that is placed upon the officials within the game of Rugby Union. As discussed previously, in addition to the substantial aerobic load, the results of this study illustrate that the referee undertakes a significant high-intensity workload, with 15.4% of the total distance covered in a match falling within the running and sprinting categories.

Alongside this is the fact that there are a considerable number of different movement pattern changes during the game, a recorded average of 1359, with associated acceleration and deceleration and multiple changes of direction occurring, placing substantial strain on the musculo-skeletal system. Also the results of this study show that the heart rate of referees rises beyond that relating to OBLA levels for, on average, 52.0% of match time, all of which questions whether the referee, in particular, should be tested and selected utilizing only an endurance capacity test as the major performance indicator.

In addition Bangsbo (1992) states that 'for well-trained athletes muscle characteristics, $\dot{V}O_2$ max and blood lactate concentration during submaximal running are not sensitive measures of endurance capacity during intermittent exercise.'

Also in support of this view, McLean (1993) states that 'rugby is not a steady state sport and demands conditioning which will facilitate anaerobic metabolism ..... the fact that a team can be successful with a moderate aerobic capacity suggests that this component of fitness, although relevant, is not a priority for development or testing.'

The specificity of generalised endurance testing and the use of the multistage fitness test, therefore, must be open to conjecture at this time. McLean (1993) also states that 'it (the multistage fitness test) fulfils many of the criteria that coaches require of a fitness test but it is debatable if the 20m shuttle run test fulfils criteria 5 and 7.' (where criterion 5 = focused on specific fitness components of the game, and criterion 7 = sensitive to change.) However McLean (1993) supports the underpinning concept of the multistage fitness test by stating that 'the 20m shuttle run test does provide a model for tests to be developed to measure other components of fitness specific to the game.'

Another issue confronting the use of the multistage fitness test is that of Rugby Football Union's stance on operating alternative field tests for the prediction of an individual's endurance capacity, i.e. the Cooper 12 minute test. Gibson et al. (1998) state that 'the multistage shuttle run often underpredicts an individual's $\dot{V}O_2$ max, particularly when the $\dot{V}O_2$ max is beyond the range of values of the healthy but untrained subjects in the original study of Leger and Lambert (1982).'

This idea is further enhanced by the findings of Gibson et al. (1998) which show that the shuttle run values of $\dot{V}O_2$ max, when compared with those obtained via direct measurements of $\dot{V}O_2$ max, underpredicted the $\dot{V}O_2$ max of runners and athletes as a whole, by between 5 and 10%. The Gibson et al. (1998) results were obtained using a sample population of males with $\dot{V}O_2$ max values ranging from 52 - 74 ml/kg/min, which shows that 'the multistage shuttle run test is more predictive of aerobic capacity in a diverse group ...... than in a homogenous group of athletes with relatively higher $\dot{V}O_2$ max values.'

These findings endorse those by Grant et al. (1995), where it was found that the multistage fitness test, on average, underpredicted $\dot{V}O_2$ max values by 4.5 ml/kg/min, a value of around 9%, when compared to direct measurement on the treadmill. Again the population sample in this study was relatively athletic, with an average $\dot{V}O_2$ max value of 60.1 ml/kg/min, suggesting that for this group the multistage fitness test's validity was open to some debate.

In conclusion there are therefore a number of question marks over the use of the current testing methodology adopted by the Rugby Football Union in terms of its validity and specificity to assessing officials' match fitness. Alternative testing protocols should be investigated in order to be utilised in the future.

6. 2. The development of a new field test for rugby officials

As the multistage fitness test's validity and specificity, when applied to the measurement of the fitness of rugby union officials, is open to some question, an attempt to design a sport specific test for rugby union officials was made.

This endeavoured to fulfil the criteria for a field test set out by McLean (1993), these being: '1, inexpensive; 2, easy to set up; 3, short in duration; 4, able to test many players simultaneously; 5, focused on specific fitness components of the game; 6 reliable and valid; and 7, sensitive to change.'

Thus a test was designed based on the work Bangsbo (1992 and 1994), which measured the relevant components of fitness, had sufficient construct validity and was more indicative of the movement patterns that officials within rugby union undertook during a match.

Bangsbo (1994) designed an intermittent field test which examined the endurance capabilities of Association Footballers and this is illustrated in diagrammatic format in Appendix P. The test was designed to incorporate a number of exercises that reflect the intermittent activity nature of a game of Association Football.

The subjects in the Bangsbo (1994) test were instructed to follow the course for a total of sixteen and one half minutes, alternating high intensity activity periods of exercise lasting fifteen seconds with low intensity recovery exercise lasting ten seconds. Thus the subjects will complete forty periods of high intensity running/jogging (ten minutes in total) and thirty-nine periods of low intensity jogging/walking (six and one half minutes in total).

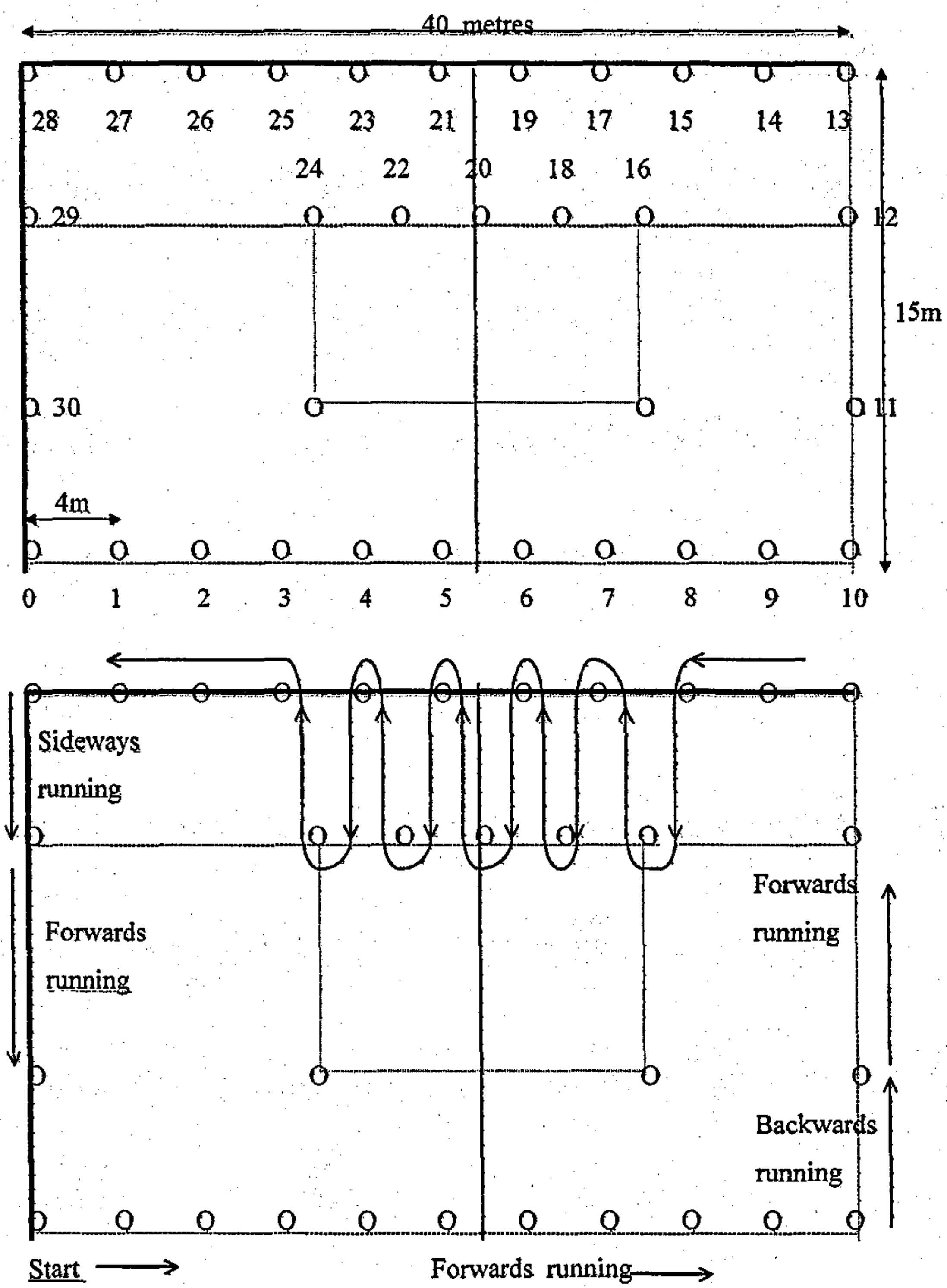
The course involves the subject running backwards and sideways at certain points in the course and also moving around posts to demonstrate agility, all of which reflects the changes of direction and the different movement patterns that a player would undertake in the game.

The test result is calculated as the total distance that the subject covers during the high intensity running phases, with the subject moving no further along the course during the intervening recovery periods. Subjects were encouraged to jog or walk towards the centre of the grid during recovery periods.

In adapting the test for rugby union officials, the basic intermittent field test developed by Bangsbo (1994) was used with several modifications. Firstly the dimensions of the course were changed to ensure that the test could be laid out easily on a rugby pitch without too much difficulty. This resulted in a reduction in lap distance from one hundred and sixty metres to one hundred and forty metres. Secondly, to reflect the percentage of distances that were covered by different movement categories recorded in this research, the movement patterns included in the test were altered. Therefore the distance covered by backwards and sideways work in the test was set at five metres per one hundred and forty metres apiece, which closely reflected the three percent sideways and backwards contributions to the match distance recorded by this research.

The resultant field test for Rugby Union officials is illustrated in Figures 10 and 11.

Figures 10 & 11 Intermittent endurance test designed for assessing Rugby Union officials' match fitness



In validating the original test, Bangsbo (1994) tested the relationship between the result of the intermittent endurance test and the correlation with the distances covered by certain subjects during several elite matches. Bangsbo (1992) stated that 'for practical purposes a simple test was desirable' and the interval field test design was 'supported by a linear relationship between the interval field test result and the match distance.' Bangsbo (1994) also states that 'it appears that the better the test result, the greater is the distance that can be covered during a match.' The correlations discovered by Bangsbo (1994) are illustrated in figure 12.

In further support of the test's validity, Bangsbo (1992) states that 'the usefulness of the interval field test is also supported by the finding that the mean blood lactate concentration was 7 mmol/l after the test. This concentration is of a similar magnitude to that found during the more intense part of soccer matches.'

This method of test analysis would be highly convenient for establishing the fitness of officials and whether the required distance in a match, as calculated in this research, could be covered by the subjects. The use of the test result and its correlation to the maximal match distance utilising the regression line in figure 12, as established by Bangsbo (1994), would allow a quick calculation of a minimum test standard to be applied to both referees and touch-judges.

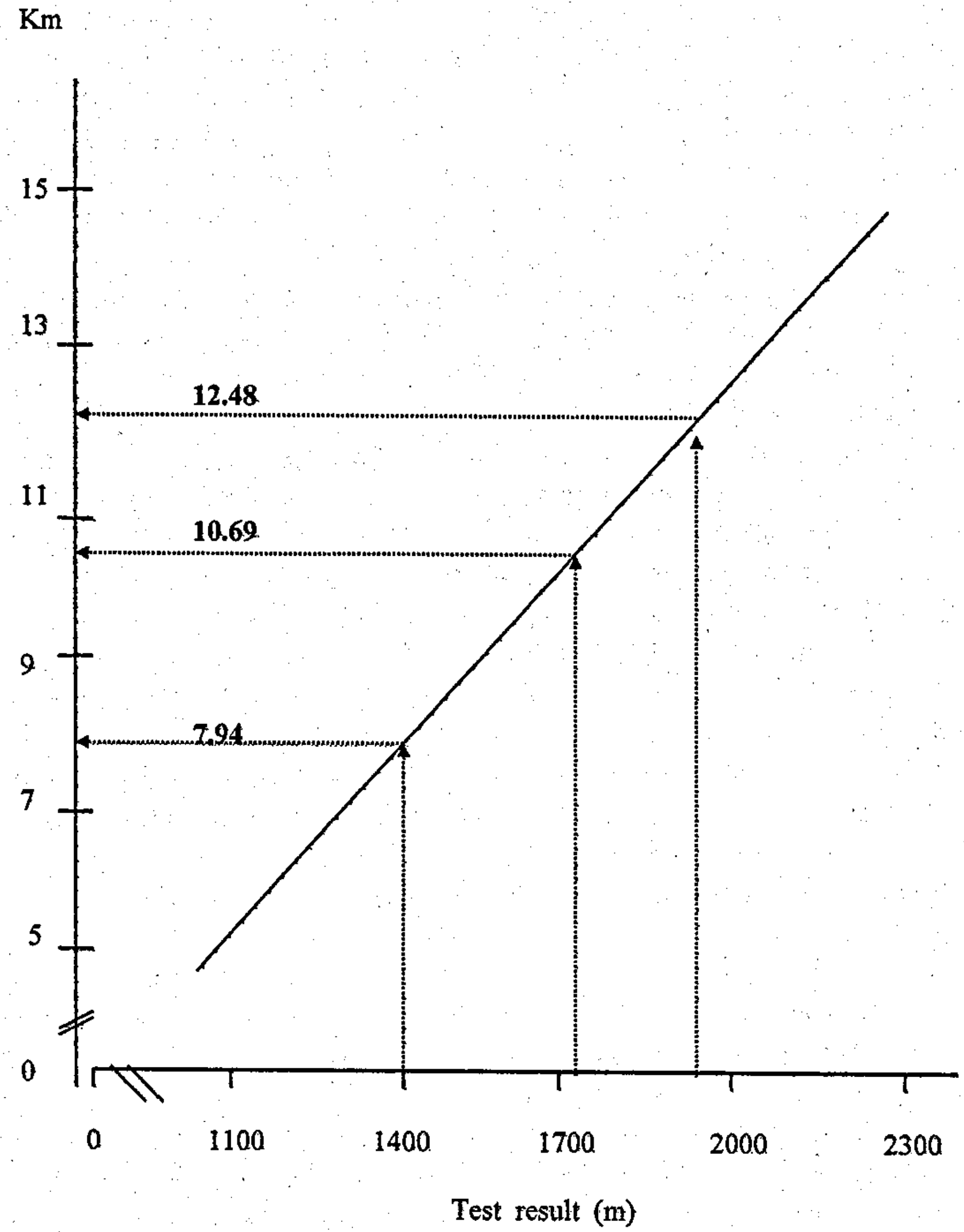


Figure 12 The relationship between the performance in the intermittent endurance test and the greatest distance that a player can cover during a match (From Bangsbo, 1994)

When using the average figures for distances covered by referees and touch-judges from this research and correlating this to figure 12, it would be possible to set minimum test standards of 1500 metres for level 1 and 2 referees, based on the mean total match distance of approximately 8000 metres, and 1100 metres for level 1 and 2 touch-judges, based on the mean total match distance of approximately 5000 metres.

It would also be possible to grade the officials according to the level of matches being taken and set test levels accordingly. It is likely that the standards for international referees would need to be higher, due to the greater speed and fitness of the game at that level and the testing level, therefore, would need to be another 100 - 200 metres higher. Likewise those officials involved in matches at levels 3 and 4 would have less test distance to cover due to the reduction in the pace and fitness of the players involved.

6. 2. 1. Methodology for assessing the specificity of the new interval field test

To assess the specificity of the test a group of subjects were measured on both the multi-stage fitness test and the adapted Bangsbo intermittent field test.

It was hypothesised that statistical analysis of the results should show no significant correlation between the two field tests, if the Bangsbo test were to be assessing other fitness factors than maximal oxygen uptake.

Twenty subjects of various ages and fitness backgrounds were taken and measured over two separate testing sessions. The individuals selected had all undertaken previous fitness testing using both the multi-stage fitness test and the adapted Bangsbo test to ensure familiarization and to reduce the learning effect. At the first testing session half of the individuals were tested using the multi-stage fitness test and the other half were tested using the new intermittent field test for rugby union as described earlier in the chapter. After an interval of a week the individuals were re-tested using the alternative test, thus enabling the subjects to be fully rested between testing sessions. This testing methodology also enabled a minimalization of any order effect.

The test conditions were standardised as closely as possible, with the multi-stage fitness test being conducted indoors on a flat, firm surface with the ambient temperature and time of the day being as similar as feasible from the first to the second session. The groups were taken through a standard ten minute warm-up, including a combination of muscular and cardio-vascular activities and a similar cool-down process on completion of the test. The test protocol, described earlier in this chapter, was closely adhered to for both groups to maximise reliability between the two testing sessions.

The new intermittent field test was equally standardised, with the test being conducted outdoors on a firm, grassy rugby pitch with similar ambient temperature, weather conditions and time of day being observed on both occasions. Again the groups were taken through a standard ten minute warm-up, including a combination of muscular and cardio-vascular activities and a similar cool-down process on completion of the test.

The test protocol, described earlier in this chapter, was closely adhered to for both groups to maximise reliability. Five subjects were tested at one time, whilst the other five rested, to ensure accuracy of result recording. This also decreased congestion within the testing area and allowed subjects the maximum opportunity to cover the largest distance possible.

6. 2. 2. Statistics

In order to statistcally analyse whether a significant correlation between the two field tests existed a Pearson's product moment correlation test was administered.

This test was selected on the bases that the data was of a parametric (ratio) nature and the relationship between two variables was being assessed, i.e. the extent to which the size and direction of the deviations from the mean in one variable (the first measurement) are related to the size and direction from the mean in the second variable (the second measurement). To ensure statistical rigour a 99% level of confidence was applied to the test ($p<0.01$).

The definition formula for Pearson's product moment correlation coefficient (*r*) is shown earlier in this chapter.

6. 3. Results of the testing sessions

The group's test results for both the multi-stage and the new intermittent field tests are shown in table XXV . The results are recorded in estimated ml/kg/min for the multi-stage fitness test and in metres covered for the intermittent field test, with group means and standard deviations shown.

Table XXV Multi-stage fitness test and intermittent field test results

SUBJECT	MULTI-STAGE TEST RESULT (ml/kg/min)	INTERMITTENT TEST RESULT (metres covered)
1	55.3	1540
2	52.3	1760
3	53.8	1550
4	51.6	1720
5	57.1	1750
6	51.6	1530
7	54.6	1450
8	49.1	1700
9	54.1	1570
10	34.1	1680
11	32.9	1300
12	33.5	1390
13	52.3	1640
14	43.1	1580
15	33.5	1450
16	44.6	1570
17	42.4	1710
18	39.9	1640
19	47.4	1690
20	57.1	1610
MEANS	47.0	1595
STD. DEV.	8.4	124

The subjects had a range of predicted $\dot{V}O_2$ max values of between 32.9 and 57.1 ml/kg/min, with a mean group score of 47.0 ml/kg/min (s.d. +/- 8.4 ml/kg/min). The distances covered in the intermittent test ranged from 1300 to 1760 metres, with a mean group score of 1591 metres (s.d. +/- 124 metres). The two sets of data were analysed using a Pearson's product correlation test and there was found to be no significant correlation ($r=.42$, $p>0.05$). The raw data for the Pearson's test is detailed in Appendix O(xiv). With only 17.6% of the common variance accounted for, the adapted intermittent field test can be regarded as significantly different from the multi-stage fitness test and it is likely that the intermittent field test measures alternative fitness criteria to the endurance capacity test.

6. 4. Discussion of the new field test for rugby union officials

The results of this study indicate that the adapted intermittent field test relies on more fitness variables than just aerobic capacity. It is probable that a certain degree of anaerobic fitness is evaluated by the test and it is feasible that this new test would be more representative of the work that an official performs in a typical game of Rugby Union. Certainly anecdotal evidence from the subject group revealed that psychologically the test proved easier to undertake, with the increased variety and likelihood of reduced risk of injury from a kinder surface.

However before a wholesale recommendation of this test can be made, there are problems with the scientific validity of the test that need to be considered. The primary concern is that the regression line drawn between the two variables in figure 16 is founded upon only three results. Bangsbo (1992) used a sample of eight male professional soccer players from 'top-class teams in Denmark' and drew up the final regression line using only three of the subjects. Bangsbo (1992) selected these subjects on the basis of the subjective observation that 'apparently only these players were close to their potential maximal distance during the observed matches' and the other subjects were ignored due to the perception that the distances covered in the matches chosen were not close to the subjects maximal. What is not clear from the research by Bangsbo (1992) is how this 'potential maximal distance' was objectively ascertained and it seems that the accuracy of this method of estimating the maximal match distance must be open to question. If the test were to be adopted for Rugby Union officials and benchmarks set for minimum fitness standards, then a recommendation of this study would be that the test is re-examined for its validity and reliability, using a much larger sample size than that which was used by Bangsbo (1992).

However the results of this study would appear to support the move away from the use of the multi-stage fitness test as a tool for ascertaining match fitness of officials and to switch to a more pertinent, intermittent-style fitness test.

CHAPTER 7

GENERAL CONCLUSIONS AND FUTURE RECOMMENDATIONS

As Rugby Union continues to adjust to the demands of professionalism, the changes to the game have been, in many senses, radical and far-reaching. The code continues to develop and alter at a considerable pace. The data presented in this study illustrates that the physiological requirements of officials have changed since the introduction of leagues and it is evident that the continual growth of professionalism will continue to place increased demands on the preparation and participation of the elite RFU officials.

The data reported in this study has shown a large increase in the distances covered by the referees since the preliminary findings of Spiller (1990) and the touch-judges now are experiencing a substantial physical workload. The supposition that a referee within a top level league match is covering over 8000 metres and a touch-judge is covering over 4900 metres means that aerobic energy provision of an official in the top flight will need to be developed beyond that which was felt to be adequate in the Spiller (1990) study. This is supported by the fact that the mean heart rates of the officials within this research are a high percentage of their maximum, particularly those in the referees group, where the mean heart rate recorded during the matches analysed was approximately 86% of maximum.

It seems reasonable to suggest that on the basis of this data that testing the ability of referees and touch-judges to provide energy from aerobic metabolism must continue with an increase beyond the original level of the proposals of Spiller (1990). The adoption of level 11 shuttle 5 on the multi-stage fitness test for referees in the 1998/99 season appears to be an appropriate one in the light of the evidence presented here. Also the fact that the touch-judges are being asked to complete 2400 metres on the Cooper 12 minute test, which would equate to level 8 shuttle 2 on the multi-stage fitness test, would seem to correspond with the aerobic demands of a level 1/2 match.

However concerns about the relevance of the current fitness testing protocols have been highlighted within this study. The suitability and validity of the multi-stage fitness test and its lack of specificity to an intermittent-style of exercise have both been discussed. Fears regarding the maximal strains placed upon relatively mature individuals, with the possibility of musculo-skeletal injuries and cardiovascular problems occurring, are a factor.

In the long term the argument for using laboratory testing on officials, where the testing can be carried out in a controlled and rigorous manner, is unequivocal. The RFU have recently made the first move towards a professional panel of referees, with three officials being placed on full-time contracts, and it seems only fitting that, with the demands on officials' fitness continuing to increase, the adoption of scientifically validated laboratory testing is seen to be a priority by the RFU.

In the short term, however, it is likely that field testing, where large numbers can be tested at little cost and in a short space of time, will continue. Taking into consideration the problems outlined with the multi-stage fitness test, the RFU should look to adopt either a sub-maximal test or, more appropriately, referee-specific tests which represent the movement patterns of a typical match.

Alongside of this argument it appears from this data that the match demands placed upon referees, in particular, are not represented by the multi-stage fitness test. The demands placed on the anaerobic pathways by the game would seem, on the basis that a referee spends 52% of the total match above the heart rate responding to the individual's OBLA level, to be substantial. There appears to be a need for a test which incorporates both aerobic and anaerobic metabolism.

This study has presented a replacement test, which has been adapted from work of Bangsbo (1994) and has put forward standards, representing the distances covered by an official within a level 1 and 2 match, earlier in the report. It is likely that further evaluation of this test, both in terms of its validity and reliability, would be required in order for the appropriate levels required by the RFU to be scientifically established.

One of the initial intentions of this research was to monitor blood lactate measurements during a match to gain an indication, alongside the recording of referees' and touch judges' heart rates, of any significant demand placed on the officials' anaerobic metabolism. Due to practical limitations highlighted in the pilot study this aspect of work was not possible. Ideally regular measurements would have been made throughout the matches, but due to the likely restrictions placed on access to the officials during play, it was really only feasible to collect samples at half-time and full-time. These results, as McLean (1992) states would 'tend to underestimate BLa concentrations during a .... match.'

Questions therefore remain over the exact contribution from anaerobic metabolism within the game. As has been stated elsewhere (Christmas et al (1998), Bangsbo (1994)), there are problems associated with using HR-$\dot{V}O_2$ correlations and values of OBLA determined by use of heart rate prediction within a laboratory situation. It would be of benefit for future studies to examine the blood lactate levels of officials within a level 1 and 2 game, as recent research on players (Deutsch et al., 1998) has shown that the lactate production can be considerable. This would be the first reported indications of the blood lactate levels of officials and would be of assistance when drawing up conclusions for future fitness testing and training protocols.

Fitness training programmes will need to be upgraded in their rigour from those put forward by Spiller (1990) and it is likely that, from the evidence of this research, officials will need to be more conscientious in match preparation. The requirement for an increase in maximal oxygen uptake and an improvement in the OBLA level appears to be a priority for officials, particularly referees, in the professional game.

It is probable that the fitness levels of the players will increase further and the International Rugby Board are likely to make the game faster and with more spectator appeal in the next few seasons by continually altering the laws of the game. Therefore the fitness testing standards suggested within this research are likely to require further evaluation as the game continues to adjust to marked changes in its structure.

CHAPTER 8

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APPENDICES

APPENDIX A Complete notation sheet for analysis of referee's movement patterns during pilot study research.

MOVEMENT PATTERN	FREQUENCY	NUMBER OF STRIDES
Walking	IIIII II	4/7/10/3/4/19/16/9/9/2/3/7/3/2/4/3/3/1/ 2/2/4/2/28/20/3/4/19/2/8/3/16/5/5/4/4/ 17/2/9/2/7/1/1/4/11/1/4/3/4/2/15/7/3/1 1/1/3/3/21/38/11/5/1/6/17/18/10/13/2/5 /1/4/8/9/5/1/8/4/3/4/8/4/47/1/2/17/6/15 /4/9/10/5/7/3/3/2/7/3
Jogging	IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII II	5/8/5/9/10/7/2/7/28/14/6/31/10/4/19/ 17/17/9/10/21/4/4/5/47/26/14/22/18/16 /6/6/7/26/5/15/11/21
Running	IIIII III	10/20/7/12/18/4//28/14
Sprinting	IIII	14/9/3/8
Walking (Back)	IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII I	2/2/1/3/2/2/5/1/2/2/1/3/1/1/1/5/1/1/3/1/ 3/3/1/1/8/1/6/6/1/6/6/1/7/3/2/6/1/2/2/5/ 1/7/2/4/4/3/1/1/4/4/7/2/1/4/3/5/8/9/8/3/ 13/5/7/3/1/7/1/5/5/6/3
Jogging (Back)	III	6/1/1
Sideways	IIIII IIIII IIIII III	2/2/1/5/1/1/1/1/1/2/1/1/3/1/2/4/2/1/1
Standing	IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII IIIII II	0

APPENDIX B Summary of baseline physiological parameters of subjects

SUBJECT	AGE (years)	HEIGHT (metres)	WEIGHT (kg)	$\dot{V}O_2$ MAX. (ml/kg/min)
1	47	1.72	75.5	54.7
2	25	1.87	80.5	50.9
3	47	1.75	84.0	55.6
4	37	1.69	69.3	59.7
5	40	1.67	70.0	51.4
6	33	1.75	83.0	56.5
7	41	1.75	79.0	57.4
8	32	1.78	75.4	67.7
9	37	1.83	77.5	50.1
10	45	1.83	88.3	54.4
MEANS	38	1.76	78.3	55.8
S.D.	7.1	0.1	6.0	5.2

APPENDIX C(i) Summary of blood lactate variables for officials' subject group

SUBJECT	RESTING LACTATE (mmol/l)	MAXIMAL LACTATE (mmol/l)
1	0.81	10.55
2	0.85	8.11
3	1.04	7.71
4	0.61	8.80
5	0.36	10.67
6	0.81	6.74
7	0.60	8.01
8	0.69	7.07
9	0.75	9.24
10	1.00	9.25
MEANS	0.75	8.62
S.D.	0.2	1.3

APPENDIX C(ii) Summary of cardiovascular variables for officials' subject group

SUBJECT	RESTING HEART RATE (bpm)	MAXIMAL HEART RATE (bpm)	AGE PREDICTED MAXIMUM (bpm)
1	51	182	173
2	75	196	195
3	56	169	173
4	67	199	183
5	64	171	180
6	66	176	187
7	60	192	179
8	54	183	188
9	75	194	183
10	49	173	175
MEANS	63	184	182
S.D.	9.3	11.1	7.1

APPENDIX C(iii) Reference heart rates, oxygen uptake and velocities at OBLA (4mmol/l) for officials' subject group

SUBJECT	HEART RATE AT OBLA (bpm/% MAX.)		OXYGEN UPTAKE AT OBLA (ml/kg/min / % MAX.)		TREADMILL VELOCITY AT OBLA (m/sec)
1	160	87.9	49.0	89.5	3.95
2	160	81.6	35.0	68.8	2.00
3	150	88.8	45.0	80.9	3.50
4	160	80.4	43.0	72.1	3.40
5	160	93.6	39.0	76.6	3.55
6	150	85.2	46.0	81.4	3.25
7	165	85.9	45.0	78.4	3.40
8	165	90.2	55.0	81.2	4.30
9	172	88.7	41.0	81.8	3.20
10	155	89.6	44.0	81.0	3.40
MEANS	160	87.2	44.2	79.2	3.40
STD. DEV.	6.82	4.00	5.45	5.71	0.59

APPENDIX D(i) Summary of total distances covered by referees' subject group

SUBJECT	DISTANCE COVERED (1st HALF) (metres)	DISTANCE COVERED (2nd HALF) (metres)	TOTAL DISTANCE COVERED IN MATCH (metres)
1	3577	3674	7252
2	4152	4193	8345
3	4352	3860	8213
4	3619	3872	7491
5	3684	3794	7478
6	3819	3948	7767
7	4814	4244	9058
8	4852	4292	9143
9	4164	4909	9073
10	3512	3524	7036
MEANS	4055	4031	8086
STD. DEV.	497	396	799

APPENDIX D(ii) Summary of percentages of total distance covered for each half for each referee in the subject group

SUBJECT	% OF TOTAL DISTANCE COVERED IN FIRST HALF	% OF TOTAL DISTANCE COVERED IN SECOND HALF
1	49.3	50.7
2	49.8	50.2
3	53.0	47.0
4	48.3	51.7
5	49.3	50.7
6	49.2	50.8
7	53.1	46.9
8	53.1	46.9
9	45.9	54.1
10	49.9	50.1
MEANS	50.1	49.9
STD. DEV.	2.35	2.35

APPENDIX E Summary of heart rate means and ranges, values relative to percentage of heart rate maximum and time spent above heart rate at OBLA (4mmol/l) for referee subject group during matches analysed.

SUBJECT	MEAN HEART RATE (bpm)	MEAN HEART RATE AS % OF HEART RATE MAXIMUM (%)	HEART RATE RANGE (bpm)	HEART RATE RANGE AS % OF HEART RATE MAXIMUM (%)	TIME SPENT ABOVE HEART RATE AT $\dot{V}$OBLA (%)
1	161	89	132-182	73-100	61.8
2	167	85	148-188	76-96	78.1
3	150	89	131-163	78-96	60.1
4	166	83	141-199	71-100	76.1
5	152	89	125-170	73-99	33.7
6	158	90	134-176	76-100	84.3
7	163	85	138-188	72-98	52.7
8	151	83	90-178	49-97	22.6
9	157	81	113-184	58-95	10.9
10	144	83	96-168	55-97	39.8
MEANS	157	86	125-180	68-98	52.0
STD. DEV.	7.6	3.2	19.2 - 10.9	10.2 - 1.9	24.7

APPENDIX F(i) Summary of total distances covered by touch-judges' subject group

SUBJECT	DISTANCE COVERED (1st HALF)	DISTANCE COVERED (2nd HALF) (metres)	TOTAL DISTANCE COVERED IN MATCH (metres)
1	2756	2000	4756
2	1907	2078	3985
3	2528	2613	5140
4	2294	2152	4447
5	2581	1906	4487
6	2359	2684	5042
7	3550	2859	6409
8	2663	2618	5281
9	2465	2619	5084
10	2211	2218	4429
MEANS	2531	2375	4906
STD. DEV.	434	338	666

APPENDIX F(ii) Summary of percentages of total distance covered for each half for each touch-judge in the subject group.

SUBJECT	% OF TOTAL DISTANCE COVERED IN FIRST HALF	% OF TOTAL DISTANCE COVERED IN SECOND
1	57.9	42.1
2	47.9	52.1
3	49.2	50.8
4	51.6	48.4
5	57.5	42.5
6	46.8	53.2
7	55.4	44.6
8	50.4	49.6
9	48.5	51.5
10	49.9	50.1
MEANS	51.5	48.5
STD. DEV.	4.02	4.02

APPENDIX G   Summary of heart rate means and ranges, values relative to percentage of heart rate maximum and time spent above heart rate at OBLA (4mmol/l) for touch-judge subject group during matches analysed.

SUBJECT	MEAN HEART RATE (bpm)	MEAN HEART RATE AS % OF HEART RATE MAXIMUM (%)	HEART RATE RANGE (bpm)	HEART RATE RANGE AS % OF HEART RATE MAXIMUM (%)	TIME SPENT ABOVE HEART RATE AT VOBLA (%)
1	88	48	60-132	33-73	0.0
2	115	59	84-158	43-81	0.0
3	114	68	70-148	41-88	0.0
4	112	56	74-165	37-83	0.5
5	102	60	80-136	47-80	0.0
6	117	67	80-153	45-87	0.5
7	126	66	105-156	55-81	0.0
8	98	54	54-151	30-83	0.0
9	114	59	78-150	40-77	0.0
10	90	52	51-146	29-84	0.0
MEANS	108	59	74-150	40-82	0.1
STD. DEV.	12.5	6.41	16.0-9.85	8.08-4.45	0.21

APPENDIX H Total and average distances and times covered by different movement categories by the referee's subject group

SUBJECT - 1 **DATE** - 5.10.96 **TIME** - 14:58 - 15:39 **HALF** - 1ST **DURATION** - 2405 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	167	525	398	3.14	2.38	1.32	14.7	16.5
Jogging	104	1847	923	17.76	8.88	2.00	51.6	38.4
Running	36	774	157	21.50	4.36	4.93	21.6	6.5
Sprinting	5	63	9	12.63	1.80	7.02	1.8	0.4
Walking (Back)	109	274	206	2.51	1.89	1.33	7.7	8.6
Jogging (Back)	9	20	9	2.17	1.00	2.17	0.5	0.4
Sideways	36	75	32	2.09	0.89	2.35	2.1	1.3
Standing	107	0	671	0.00	6.27	0.00	0.0	27.9
TOTALS	573	3577	2405	6.24	4.20	1.49	100	100

SUBJECT - 1 **DATE** - 5.10.96 **TIME** - 15:43 - 16:23 **HALF** - 2ND **DURATION** - 2410 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	194	645	468	3.33	2.41	1.38	17.6	19.4
Jogging	112	1717	858	15.33	7.66	2.00	46.7	35.6
Running	40	875	172	21.87	4.30	5.09	23.8	7.2
Sprinting	6	51	7	8.47	1.17	7.26	1.4	0.3
Walking (Back)	125	277	208	2.22	1.66	1.33	7.5	8.6
Jogging (Back)	11	29	13	2.59	1.18	2.19	0.8	0.5
Sideways	39	81	34	2.06	0.87	2.37	2.2	1.4
Standing	106	0	650	0.00	6.13	0.00	0.0	27.0
TOTALS	633	3674	2410	5.80	3.80	1.53	100	100

SUBJECT - 2 **DATE** - 5.11.96 **TIME** - 16:01 - 16:43 **HALF** - 1ST **DURATION** - 2390 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	195	879	502	4.51	2.57	1.75	23.9	21.0
Jogging	90	1915	861	21.28	9.57	2.22	52.0	36.0
Running	18	370	62	20.53	3.44	5.96	10.0	2.6
Sprinting	1	34	4	34.2	4.00	8.55	0.9	0.2
Walking (Back)	148	388	233	2.62	1.57	1.67	10.6	9.7
Jogging (Back)	7	23	9	3.25	1.29	2.53	0.6	0.4
Sideways	24	75	23	3.12	0.96	3.26	2.0	1.0
Standing	97	0	696	0.00	7.18	0.00	0.0	29.1
TOTALS	698	3684	2405	5.28	3.45	1.53	100	100

SUBJECT - 2 **DATE** - 5.11.96 **TIME** - 16:49 - 17:29 **HALF** - 2ND **DURATION** - 2300 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	182	986	600	5.42	3.30	1.64	26.0	26.1
Jogging	86	1742	779	20.25	9.06	2.24	45.9	33.9
Running	23	521	92	22.67	4.00	5.67	13.8	4.0
Sprinting	2	41	5	20.52	2.50	8.21	1.1	0.2
Walking (Back)	140	339	238	2.42	1.70	1.42	8.9	10.4
Jogging (Back)	15	43	21	2.85	1.40	2.04	1.1	0.9
Sideways	43	122	39	2.84	0.91	3.13	3.2	1.7
Standing	85	0	524	0.00	6.16	0.00	0.0	22.8
TOTALS	576	3794	2300	6.59	3.99	1.65	100	100

SUBJECT - 3 **DATE** - 26.10.96 **TIME** - 14:57 - 15:52 **HALF** - 1ST **DURATION** - 2630 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	241	961	604	3.99	2.51	1.59	22.1	23.0
Jogging	125	2080	898	16.63	7.18	2.32	47.8	34.2
Running	34	613	114	18.03	3.35	5.38	14.1	4.3
Sprinting	6	80	11	13.36	1.83	7.30	1.9	0.4
Walking (Back)	160	453	310	2.83	1.94	1.51	10.4	11.8
Jogging (Back)	18	59	21	3.25	1.17	2.78	1.3	0.8
Sideways	44	106	28	2.42	0.64	3.78	2.4	1.1
Standing	109	0	644	0.00	5.91	0.00	0.0	24.4
TOTALS	737	4352	2630	5.90	3.57	1.65	100	100

SUBJECT - 3 **DATE** - 26.10.96 **TIME** - 15:46 - 16:26 **HALF** - 2ND **DURATION** - 2397 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	209	819	518	3.92	2.48	1.58	21.2	21.6
Jogging	107	1973	818	18.44	7.64	2.41	51.1	34.1
Running	23	465	91	20.20	3.96	5.10	12.0	3.8
Sprinting	6	89	12	14.75	2.00	7.38	2.3	0.5
Walking (Back)	141	370	250	2.63	1.77	1.49	9.6	10.4
Jogging (Back)	16	53	21	3.32	1.31	2.53	1.4	0.9
Sideways	41	91	29	2.22	0.71	3.13	2.4	1.2
Standing	121	0	658	0.00	5.44	0.00	0.0	27.5
TOTALS	664	3860	2397	5.81	3.61	1.61	100	100

SUBJECT - 4 **DATE** - 4.11.96 **TIME** - 20:29 - 21:10 **HALF** - 1ST **DURATION** - 2405 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	184	764	425	4.15	2.31	1.80	21.1	17.7
Jogging	94	1639	772	17.43	8.21	2.12	45.3	32.1
Running	26	344	60	13.23	2.31	5.73	9.5	2.5
Sprinting	6	105	15	17.5	2.50	7.00	2.9	0.6
Walking (Back)	137	361	282	2.64	2.06	1.28	10.0	11.7
Jogging (Back)	25	86	29	3.43	1.16	2.96	2.4	1.2
Sideways	103	320	118	3.11	1.15	2.70	8.8	4.9
Standing	123	0	704	0.00	5.72	0.00	0.0	29.3
TOTALS	698	3619	2405	5.18	3.45	1.50	100	100

SUBJECT - 4 **DATE** - 4.11.96 **TIME** - 21:14 - 21:57 **HALF** - 2ND **DURATION** - 2526 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	189	969	500	5.13	2.65	1.94	25.0	19.8
Jogging	94	1472	734	15.66	7.81	2.01	38.0	29.0
Running	32	523	90	16.36	2.81	5.82	13.5	3.6
Sprinting	6	102	14	17.00	2.33	7.29	2.7	0.6
Walking (Back)	175	484	365	2.77	2.09	1.33	12.5	14.4
Jogging (Back)	17	49	19	2.88	1.12	2.57	1.3	0.8
Sideways	98	272	99	2.78	1.01	2.75	7.0	3.9
Standing	152	0	705	0.00	4.47	0.00	0.0	27.9
TOTALS	763	3872	2526	5.08	3.05	1.67	100	100

SUBJECT - 5 **DATE** - 16.10.96 **TIME** - 19:27 - 20:08 **HALF** - 1ST **DURATION** - 2462 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	183	830	472	4.53	2.58	1.76	20.0	19.2
Jogging	125	2103	971	16.82	7.77	2.16	50.6	39.4
Running	31	651	110	20.99	3.55	5.91	15.7	4.5
Sprinting	7	123	17	17.60	2.71	7.25	3.0	0.7
Walking (Back)	116	2867	212	2.47	1.83	1.35	6.9	8.6
Jogging (Back)	19	58	22	3.06	1.16	2.64	1.4	0.9
Sideways	30	102	29	3.38	0.97	3.48	2.4	1.2
Standing	97	0	629	0.00	6.48	0.00	0.0	25.5
TOTALS	608	4152	2462	6.83	4.05	1.69	100	100

SUBJECT - 5 **DATE** - 16.10.96 **TIME** - 20:13 - 20:53 **HALF** - 2ND **DURATION** - 2402 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	168	1054	633	6.28	3.77	1.67	25.2	26.3
Jogging	109	1806	782	16.57	7.17	2.31	43.1	32.6
Running	36	733	129	20.36	3.58	5.69	17.5	5.4
Sprinting	10	168	23	16.8	2.30	7.30	4.0	0.9
Walking (Back)	114	264	189	2.32	1.66	1.40	6.3	7.9
Jogging (Back)	22	73	25	3.31	1.14	2.90	1.7	1.0
Sideways	33	94	26	2.86	0.79	3.62	2.2	1.1
Standing	99	0	595	0.00	6.01	0.00	0.0	24.8
TOTALS	591	4193	2402	7.09	4.06	1.75	100	100

SUBJECT - 6 **DATE** - 8.2.97 **TIME** - 15:01-15:42 **HALF** - 1ST **DURATION** - 2355 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	199	714	457	3.59	2.30	1.56	14.8	19.4
Jogging	124	2795	755	22.54	6.09	3.70	58.1	32.0
Running	30	630	110	21.01	3.67	5.72	13.1	4.7
Sprinting	4	60	7	15.03	1.75	8.59	1.2	0.3
Walking (Back)	162	442	304	2.73	1.88	1.45	9.2	12.9
Jogging (Back)	14	43	18	3.09	1.29	2.40	0.9	0.8
Sideways	52	128	49	2.47	0.94	2.63	2.7	2.1
Standing	132	0	655	0	4.94	0	0	27.8
TOTALS	717	4814	2355	6.71	3.28	2.05	100	100

SUBJECT - 6 **DATE** - 8.2.97 **TIME** - 15:46 - 16:28 **HALF** - 2ND **DURATION** - 2504 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	240	899	591	3.75	2.46	1.52	21.2	23.6
Jogging	112	1858	653	16.59	5.83	2.85	43.8	26.1
Running	28	763	125	27.26	4.46	6.11	18.0	5.0
Sprinting	2	30	4	15.03	2.00	7.51	0.7	0.2
Walking (Back)	188	490	329	2.61	1.75	1.49	11.5	13.1
Jogging (Back)	19	31	11	1.64	0.58	2.83	0.7	0.4
Sideways	75	173	68	2.31	0.91	2.54	4.1	2.7
Standing	175	0	723	0	4.13	0	0	28.9
TOTALS	839	4244	2504	5.06	2.98	1.70	100	100

SUBJECT - 7 **DATE** - 23.2.97 **TIME** - 15:01 - 15:43 **HALF** - 1ST **DURATION** - 2491 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	234	920	532	3.93	2.27	1.73	22.1	21.4
Jogging	109	1860	711	17.06	6.52	2.62	44.7	28.5
Running	22	471	69	21.4	3.14	6.82	11.3	2.8
Sprinting	1	10	1	9.9	1.00	9.9	0.2	0.04
Walking (Back)	202	638	365	3.16	1.81	1.75	15.3	14.7
Jogging (Back)	18	96	31	5.36	1.72	3.12	2.3	1.2
Sideways	54	169	44	3.14	0.81	4.21	4.1	1.8
Standing	127	0	738	0	5.81	0	0	29.6
TOTALS	767	4164	2491	5.43	3.25	1.67	100	100

SUBJECT - 7 **DATE** - 23.2.97 **TIME** - 15:48 - 16:31 **HALF** - 2ND **DURATION** - 2540 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	221	1067	610	4.83	2.76	1.75	21.7	24.0
Jogging	123	2460	781	20	6.35	3.15	50.1	30.7
Running	24	432	62	18.02	2.58	6.98	8.8	2.4
Sprinting	2	76	9	37.95	4.5	8.43	1.6	0.4
Walking (Back)	165	674	377	4.08	2.28	1.79	13.7	14.8
Jogging (Back)	15	72	22	4.81	1.47	3.27	1.5	0.9
Sideways	49	128	37	2.61	0.76	3.43	2.6	1.5
Standing	119	0	642	0	5.39	0	0	25.3
TOTALS	718	4909	2540	6.84	3.54	1.93	100	100

SUBJECT - 8 **DATE** - 22.2.97 **TIME** - 15:01 - 15:43 **HALF** - 1ST **DURATION** - 2493 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	200	1149	617	5.75	3.09	1.86	23.7	24.7
Jogging	128	2121	817	16.57	6.38	2.60	43.7	32.8
Running	33	649	93	19.67	2.82	6.98	13.4	3.7
Sprinting	2	30	4	15.21	2.00	7.61	0.6	0.2
Walking (Back)	158	412	260	2.61	1.65	1.58	8.5	10.4
Jogging (Back)	44	214	60	4.87	1.36	3.58	4.4	2.4
Sideways	99	276	74	2.79	0.75	3.72	5.7	3.0
Standing	150	0	568	0	3.79	0	0	22.8
TOTALS	814	4852	2493	5.96	3.06	1.95	100	100

SUBJECT - 8 **DATE** - 22.2.97 **TIME** - 15:47 - 16:30 **HALF** - 2ND **DURATION** - 2342 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	218	993	542	4.55	2.49	1.83	23.1	23.1
Jogging	106	1955	757	18.44	7.14	2.58	45.6	32.3
Running	33	517	79	15.67	2.39	6.56	12.1	3.3
Sprinting	1	20	2	20.28	2.00	10.14	0.5	0.1
Walking (Back)	161	378	231	2.35	1.43	1.64	8.8	9.9
Jogging (Back)	31	151	41	4.88	1.32	3.70	3.5	1.8
Sideways	87	277	68	3.19	0.78	4.09	6.4	2.9
Standing	121	0	546	0	4.51	0	0	23.3
TOTALS	758	4292	2342	5.66	3.09	1.83	100	100

SUBJECT - 9 **DATE** - 7.12.96 **TIME** - 14:02 - 14:45 **HALF** - 1ST **DURATION** - 2340 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	182	758	467	4.16	2.57	1.79	19.8	20.0
Jogging	103	1867	782	18.12	7.59	2.39	48.9	33.4
Running	25	641	101	25.65	4.04	6.35	16.8	4.3
Sprinting	5	67	8	13.38	1.60	8.36	1.8	0.3
Walking (Back)	107	326	240	3.05	2.24	1.36	8.5	10.3
Jogging (Back)	12	53	16	4.45	1.33	3.35	1.4	0.7
Sideways	37	107	34	2.88	0.92	3.13	2.8	1.4
Standing	125	0	696	0	5.57	0	0	29.6
TOTALS	596	3819	2340	6.41	3.93	1.63	100	100

SUBJECT - 9 **DATE** - 7.12.96 **TIME** - 14:48 - 15:31 **HALF** - 2ND **DURATION** - 2450 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	177	879	519	4.97	2.93	1.70	22.3	21.2
Jogging	97	2124	836	21.90	8.62	2.54	53.8	34.1
Running	25	489	75	19.55	3.00	6.52	12.4	3.1
Sprinting	2	25	3	12.32	1.50	8.21	0.6	0.1
Walking (Back)	116	312	194	2.69	1.67	1.61	7.9	7.9
Jogging (Back)	12	47	13	3.91	1.08	3.62	1.2	0.5
Sideways	27	72	25	2.68	0.93	2.88	1.8	1.0
Standing	109	0	785	0	7.20	0	0	32.1
TOTALS	565	3948	2450	6.99	4.34	1.61	100	100

SUBJECT - 10 **DATE** - 22.3.97 **TIME** - 15:58 - 16:40 **HALF** - 1ST **DURATION** - 2455 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	230	930	555	4.05	2.41	1.68	26.5	22.5
Jogging	100	1598	711	15.98	7.11	2.25	45.5	29.0
Running	23	323	49	14.04	2.13	6.59	9.2	2.0
Sprinting	1	18	2	17.8	2.00	8.90	0.5	0.1
Walking (Back)	154	428	314	2.78	2.04	1.36	12.2	12.8
Jogging (Back)	22	78	27	3.55	0.81	4.38	2.2	1.1
Sideways	44	137	39	3.12	0.89	3.51	3.9	1.6
Standing	110	0	758	0	6.89	0	0	30.9
TOTALS	684	3512	2455	5.13	3.59	1.43	100	100

SUBJECT - 10 **DATE** - 22.3.97 **TIME** - 16:45 -17:29 **HALF** - 2ND **DURATION** - 2414 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	235	960	566	4.09	2.41	1.70	27.2	23.4
Jogging	111	1469	649	13.23	5.85	2.26	41.7	26.9
Running	26	454	75	17.46	2.04	6.05	12.9	3.1
Sprinting	2	28	3	14.24	1.50	9.49	0.8	0.1
Walking (Back)	162	444	329	2.74	2.03	1.35	12.6	13.6
Jogging (Back)	15	50	15	3.33	1.00	3.33	1.4	0.6
Sideways	41	119	37	2.89	0.90	3.21	3.4	1.5
Standing	116	0	719	0	6.20	0	0	29.8
TOTALS	708	3524	2414	4.98	3.41	1.46	100	100

APPENDIX I   Total and average distances and times covered by different movement categories by the touch-judges' subject group

SUBJECT - 1   **DATE** - 11.2.97   **TIME** - 19:29 - 20:11   **HALF** - 1ST   **DURATION** - 2478 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	161	863	627	5.36	3.89	1.38	31.3	25.3
Jogging	65	1509	552	23.21	8.49	2.73	54.7	22.3
Running	10	233	44	23.29	4.40	5.29	8.5	1.8
Sprinting	0	0	0	0.00	0.00	0.00	0.0	0.0
Walking (Back)	59	115	97	1.94	1.64	1.18	4.2	3.9
Jogging (Back)	1	2	1	2.25	1.00	2.25	0.1	0.1
Sideways	15	34	16	2.29	1.07	2.15	1.2	0.6
Standing	101	0	1141	0.00	11.30	0.00	0.0	46.0
TOTALS	412	2756	2478	6.69	6.01	1.11	100	100

SUBJECT - 1 **DATE** - 11.2.97 **TIME** - 20:16 - 20:57 **HALF** - 2ND **DURATION** - 2462 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	181	794	605	4.39	3.34	1.31	39.7	24.6
Jogging	50	898	446	8.92	8.92	2.01	44.9	18.1
Running	9	148	29	16.41	3.22	5.09	7.4	1.2
Sprinting	0	0	0	0.00	0.00	0.00	0.0	0.0
Walking (Back)	75	124	107	1.65	1.43	1.15	6.1	4.3
Jogging (Back)	1	2	1	1.50	1.00	1.50	0.1	0.1
Sideways	18	36	18	1.98	1.00	1.98	1.8	0.7
Standing	112	0	1256	0.00	11.21	0.00	0.0	51.0
TOTALS	446	2000	2462	4.48	5.52	0.81	100	100

SUBJECT - 2 **DATE** - 29.10.97 **TIME** - 16:32-17:18 **HALF** - 1ST **DURATION** - 2410 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	142	802	517	5.65	3.64	1.55	42.1	21.4
Jogging	36	716	310	19.88	8.61	2.31	37.5	12.9
Running	6	81	15	13.48	2.43	5.55	4.3	0.6
Sprinting	1	14	2	13.68	1.72	7.97	0.7	0.1
Walking (Back)	94	168	129	1.78	1.37	1.30	8.8	5.4
Jogging (Back)	15	107	44	7.16	2.93	2.44	5.6	1.8
Sideways	8	20	8	2.45	1.05	2.33	1.0	0.3
Standing	97	0	1385	0.00	14.28	0.00	0.0	57.5
TOTALS	399	1907	2410	4.78	6.04	0.79	100	100

SUBJECT - 2 **DATE** - 29.10.97 **TIME** - 19:23-20:16 **HALF** - 2ND **DURATION** - 2478 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	150	910	591	6.07	3.94	1.54	43.8	23.9
Jogging	42	770	348	18.34	8.30	2.21	37.1	14.0
Running	5	70	12	14.03	2.44	5.76	3.4	0.5
Sprinting	1	12	2	12.05	1.50	8.03	0.6	0.1
Walking (Back)	90	165	137	1.84	1.52	1.21	8.0	5.5
Jogging (Back)	17	125	52	7.38	3.05	2.42	6.0	2.1
Sideways	10	24	10	2.45	1.03	2.37	1.1	0.4
Standing	99	0	1326	0.00	13.39	0.00	0.0	53.5
TOTALS	414	2078	2478	5.02	5.99	0.84	100	100

SUBJECT - 3 **DATE** - 4.11.96 **TIME** - 20:29 - 21:10 **HALF** - 1ST **DURATION** - 2405 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	156	676	423	4.33	2.71	1.60	26.7	17.6
Jogging	81	1065	528	13.15	6.52	2.01	42.1	22.0
Running	18	515	97	28.62	5.39	5.31	20.4	4.0
Sprinting	4	63	10	15.87	2.50	7.05	2.5	0.4
Walking (Back)	33	68	64	2.06	1.94	1.06	2.7	2.7
Jogging (Back)	1	5	2	4.50	2.00	2.25	0.2	0.1
Sideways	58	136	65	2.34	1.12	2.09	5.4	2.7
Standing	128	0	1216	0.00	9.50	0.00	0.0	50.5
TOTALS	479	2528	2405	5.28	5.02	1.05	100	100

SUBJECT - 3 **DATE** - 4.11.96 **TIME** - 21:14 - 21:57 **HALF** - 2ND **DURATION** - 2526 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	168	845	541	5.03	3.22	1.56	32.3	21.4
Jogging	63	1134	520	18.01	8.25	2.18	43.4	20.6
Running	16	428	82	26.76	5.13	5.22	16.4	3.2
Sprinting	3	50	8	16.70	2.67	7.16	1.9	0.3
Walking (Back)	33	58	52	1.75	1.58	1.11	2.2	2.1
Jogging (Back)	1	4	1	3.60	1.00	3.60	0.2	0.04
Sideways	44	94	41	2.13	0.93	2.29	3.6	1.6
Standing	140	0	1281	0.0	9.15	0.00	0.0	50.7
TOTALS	479	2613	2405	5.45	5.02	1.09	100	100

SUBJECT - 4 **DATE** - 16.11.96 **TIME** - 14:59 - 15:41 **HALF** - 1ST **DURATION** - 2440 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	144	745	462	5.18	3.21	1.61	32.5	18.9
Jogging	56	1051	499	18.77	8.91	2.11	45.8	20.5
Running	7	109	18	15.54	2.57	6.04	4.8	0.7
Sprinting	1	18	2	18.00	2.00	9.00	0.8	0.1
Walking (Back)	67	111	103	1.65	1.54	1.08	4.8	4.2
Jogging (Back)	5	12	7	2.45	1.40	2.04	0.5	0.3
Sideways	72	248	112	3.45	1.56	2.22	10.8	4.6
Standing	143	0	1237	0.00	8.65	0.00	0.0	50.7
TOTALS	495	2294	2440	4.64	4.93	0.94	100	100

SUBJECT - 4 **DATE** - 16.11.96 **TIME** - 15:46 - 16:28 **HALF** - 2ND **DURATION** - 2287 seconds

STRIDE PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (secs)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	149	935	604	6.27	4.05	1.55	43.4	26.4
Jogging	58	774	376	13.34	6.48	2.06	36.0	16.4
Running	7	72	12	10.30	1.71	6.01	3.3	0.5
Sprinting	3	102	14	34	4.67	7.29	4.7	0.6
Walking (Back)	61	873	80	1.43	1.31	1.09	4.1	3.5
Jogging (Back)	8	17	8	2.16	1.00	2.16	0.8	0.3
Sideways	57	165	87	2.90	1.53	1.90	7.7	3.8
Standing	144	0	1106	0.00	7.68	0.00	0.0	48.4
TOTALS	479	2152	2405	4.49	5.02	0.89	100	100

SUBJECT - 5 **DATE** - 4.1.97 **TIME** - 15:00 - 15:42 **HALF** - 1ST **DURATION** - 2400 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	215	883	668	4.11	3.11	1.32	34.2	27.8
Jogging	59	1149	488	19.48	8.27	2.36	44.6	20.3
Running	12	205	38	17.10	3.17	5.40	8.0	1.6
Sprinting	1	28	4	28.00	4.00	7.00	1.1	0.2
Walking (Back)	113	169	162	1.49	1.43	1.04	6.5	6.8
Jogging (Back)	9	55	20	6.10	2.22	2.75	2.1	0.8
Sideways	23	91	29	3.97	1.26	3.15	3.5	1.2
Standing	112	0	991	0.00	8.85	0.00	0.0	41.3
TOTALS	544	2581	2400	4.74	4.41	1.07	100	100

SUBJECT - 5 **DATE** - 4.1.97 **TIME** - 15:46 - 16:30 **HALF** - 2ND **DURATION** - 2260 seconds

STRIDE PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (secs)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	177	834	641	4.71	3.62	1.30	43.8	28.4
Jogging	50	721	362	14.42	7.24	1.99	37.8	16.0
Running	6	78	13	13.05	2.17	6.02	4.1	0.6
Sprinting	0	0	0	0.00	0.00	0.00	0.0	0.0
Walking (Back)	88	162	150	1.84	1.70	1.08	8.5	6.6
Jogging (Back)	8	36	12	4.51	1.25	3.01	1.9	0.5
Sideways	25	74	25	2.96	1.00	2.96	3.9	1.1
Standing	109	0	1057	0.00	9.70	0.00	0.0	46.8
TOTALS	561	1906	2260	3.40	4.03	0.84	100	100

SUBJECT - 6 **DATE** - 30.12.97 **TIME** - 15:02 - 15:46 **HALF** - 1ST **DURATION** - 2410 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	175	723	502	4.13	2.87	1.44	30.7	20.8
Jogging	61	914	287	14.98	4.70	3.18	38.7	11.9
Running	10	179	28	17.85	2.80	6.38	7.6	1.2
Sprinting	2	37	5	18.37	2.50	7.35	1.6	0.2
Walking (Back)	134	321	235	2.40	1.75	1.37	13.6	9.8
Jogging (Back)	3	6	3	2.13	1.00	2.13	0.3	0.1
Sideways	49	178	65	3.64	1.33	2.74	7.5	2.7
Standing	120	0	1285	0.00	10.71	0.00	0.0	53.3
TOTALS	554	2359	2410	4.26	4.35	0.98	100	100

SUBJECT - 6 **DATE** - 30.12.97 **TIME** - 15:56 - 16:40 **HALF** - 2ND **DURATION** - 2302 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	167	734	479	4.40	2.87	1.53	27.4	20.8
Jogging	61	1213	362	19.89	5.93	3.35	45.2	15.7
Running	13	213	33	16.41	2.54	6.46	8.0	1.4
Sprinting	4	47	6	11.69	1.50	7.79	1.7	0.3
Walking (Back)	123	290	194	2.36	1.58	1.50	10.8	8.4
Jogging (Back)	7	25	11	3.54	1.57	2.25	0.9	0.5
Sideways	30	161	58	5.37	1.93	2.78	6.0	2.5
Standing	115	0	1159	0.00	10.08	0.00	0.0	50.4
TOTALS	520	2684	2302	5.16	4.43	1.17	100	100

SUBJECT - 7 **DATE** - 21.12.96 **TIME** - 14:07 - 14:48 **HALF** - 1ST **DURATION** - 2427 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	214	1048	610	4.90	2.85	1.72	29.5	25.1
Jogging	68	1740	616	25.59	9.06	2.82	49.0	25.4
Running	11	242	40	21.97	3.64	6.04	6.8	1.6
Sprinting	2	43	6	21.45	3.00	7.15	1.2	0.2
Walking (Back)	114	278	188	2.44	1.65	1.48	7.8	7.8
Jogging (Back)	17	93	36	5.48	2.12	2.58	2.6	1.5
Sideways	39	106	34	2.72	0.87	3.13	3.0	1.4
Standing	133	0	897	0	6.74	0	0	37.0
TOTALS	568	3550	2427	6.25	4.27	1.46	100	100

SUBJECT - 7 **DATE** - 21.12.96 **TIME** - 14:53 - 15:34 **HALF** - 2ND **DURATION** - 2420 seconds

STRIDE PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (secs)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	210	1022	661	4.87	3.15	1.54	35.7	27.3
Jogging	51	1179	454	23.12	8.90	2.60	41.2	18.8
Running	12	197	31	16.43	2.58	6.37	6.9	1.3
Sprinting	2	56	8	28.05	4.00	7.01	2.0	0.3
Walking (Back)	81	179	134	2.21	1.65	1.34	6.3	5.5
Jogging (Back)	18	83	34	4.59	1.89	2.43	2.9	1.4
Sideways	36	143	47	3.98	1.31	3.04	5.0	2.0
Standing	151	0	1051	0	6.96	0	0	43.4
TOTALS	561	2859	2420	5.10	4.31	1.18	100	100

SUBJECT - 8 **DATE** - 22.10.97 **TIME** - 15:00 - 15:46 **HALF** - 1ST **DURATION** - 2360 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	173	965	451	5.58	2.61	1.54	36.2	19.1
Jogging	72	1214	544	16.86	7.56	2.23	45.6	23.1
Running	10	212	39	21.22	3.92	5.42	8.0	1.7
Sprinting	1	25	3	25.12	3.15	7.97	0.9	0.1
Walking (Back)	77	134	119	1.74	1.54	1.13	0.1	5.0
Jogging (Back)	6	11	5	1.86	0.87	2.13	0.4	0.2
Sideways	21	101	44	4.83	2.09	2.31	3.8	1.9
Standing	115	0	1154	0.00	10.04	0.00	0.0	48.9
TOTALS	475	2663	2360	5.61	4.97	1.13	100	100

SUBJECT - 8 **DATE** - 22.10.97. **TIME** - 15:57 - 16:40 **HALF** - 2ND **DURATION** - 2420 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	177	977	665	5.52	3.76	1.47	37.3	27.5
Jogging	70	1165	511	16.65	7.30	2.28	44.5	21.1
Running	9	199	37	22.06	4.08	5.41	7.6	1.5
Sprinting	1	20	3	20.17	2.51	8.02	0.8	0.1
Walking (Back)	73	117	102	1.60	1.39	1.15	4.5	4.2
Jogging (Back)	7	18	8	2.60	1.18	2.21	0.7	0.3
Sideways	22	122	54	5.53	2.44	2.27	4.6	2.2
Standing	121	0	1041	0.00	8.61	0.00	0.0	43.0
TOTALS	480	2618	2420	5.45	5.04	1.08	100	100

SUBJECT - 9 **DATE** - 15.4.97 **TIME** - 19:13 - 19:53 **HALF** - 1ST **DURATION** - 2407 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	157	662	468	4.22	2.98	1.41	26.9	19.4
Jogging	80	1478	596	18.48	7.45	2.48	60.0	24.8
Running	6	105	17	17.49	2.83	6.17	4.3	0.7
Sprinting	0	0	0	0.00	0.00	0.00	0.0	0.0
Walking (Back)	58	106	95	1.83	1.64	1.11	4.3	4.0
Jogging (Back)	6	38	10	6.36	1.67	3.82	1.5	0.4
Sideways	34	75	26	2.21	0.76	2.89	3.0	1.1
Standing	119	0	1195	0.00	10.04	0.00	0.0	49.6
TOTALS	460	2465	2407	5.36	5.23	1.02	100	100

SUBJECT - 9 **DATE** - 15.4.97 **TIME** - 19:57 - 20:43 **HALF** - 2ND **DURATION** - 2526 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	173	716	498	4.14	2.88	1.44	27.3	19.7
Jogging	76	1513	599	19.91	7.88	2.53	57.8	23.7
Running	10	167	26	16.73	2.60	6.43	6.4	1.0
Sprinting	2	35	4	17.6	2.00	8.80	1.3	0.1
Walking (Back)	43	70	63	1.63	1.47	1.11	2.7	2.5
Jogging (Back)	4	39	9	9.81	2.25	4.36	1.5	0.4
Sideways	31	78	27	2.52	0.87	2.89	3.0	1.1
Standing	105	0	1300	0.00	12.38	0.00	0.0	51.5
TOTALS	444	2619	2526	5.90	5.67	1.04	100	100

SUBJECT - 10 **DATE** - 29.3.97 **TIME** - 15:02 - 15:43 **HALF** - 1ST **DURATION** - 2410 seconds

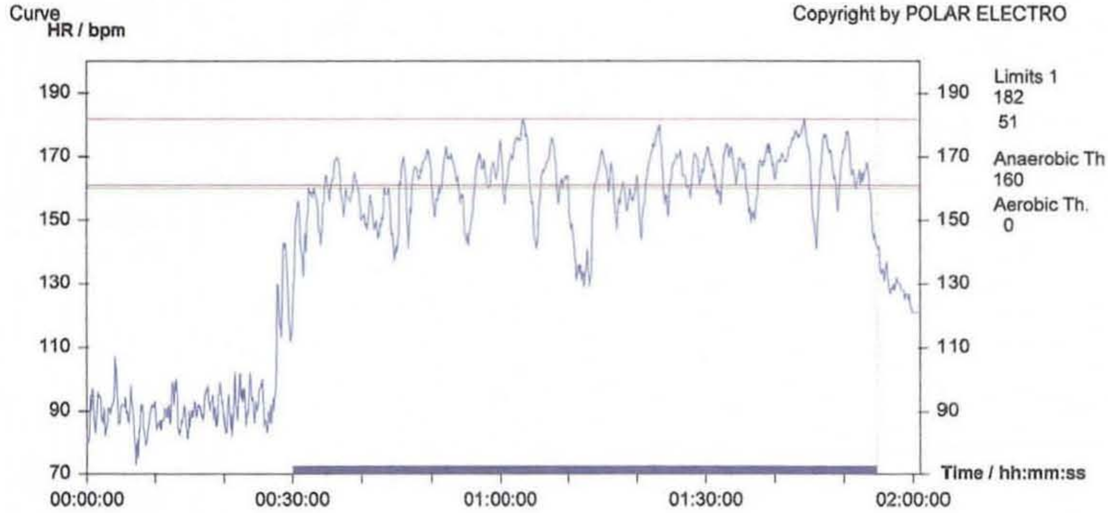
MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	185	777	616	4.20	3.33	1.26	35.1	25.6
Jogging	47	893	430	19.00	9.15	2.08	40.4	17.8
Running	11	241	39	21.95	3.55	6.18	10.9	1.6
Sprinting	1	14	2	14.24	2.00	7.12	0.6	0.1
Walking (Back)	103	173	162	1.68	1.57	1.07	7.9	6.7
Jogging (Back)	0	0	0	0.00	0.00	0.00	0.0	0.0
Sideways	35	112	28	3.21	0.80	4.01	5.1	1.2
Standing	128	0	1133	0.00	8.86	0.00	0.0	47.0
TOTALS	510	2211	2410	4.34	4.73	0.92	100	100

SUBJECT - 10   **DATE** - 29.3.97   **TIME** - 15:47 - 16:28   **HALF** - 2ND   **DURATION** - 2365 seconds

MOVEMENT PATTERN	FREQUENCY	TOTAL DISTANCE COVERED (metres)	TOTAL TIME SPENT (seconds)	AVERAGE DISTANCE PER MOVEMENT SEGMENT (metres)	AVERAGE TIME PER MOVEMENT SEGMENT (seconds)	AVERAGE VELOCITY PER MOVEMENT SEGMENT (metres/second)	PERCENTAGE OF TOTAL DISTANCE COVERED IN HALF (%)	PERCENTAGE OF TOTAL TIME SPENT IN HALF (%)
Walking	174	720	586	4.14	3.37	1.23	32.5	24.8
Jogging	55	1071	520	19.48	9.58	2.06	48.3	22.3
Running	11	245	44	22.25	3.36	5.56	11.0	1.5
Sprinting	1	14	2	14.24	2.00	7.12	0.7	0.1
Walking (Back)	87	122	112	1.41	1.29	1.09	5.5	4.7
Jogging (Back)	2	2	1	1.04	0.50	2.08	0.1	0.1
Sideways	17	43	12	2.54	0.71	3.59	1.9	0.5
Standing	111	0	1088	0	9.80	0.00	0.0	46.0
TOTALS	458	2218	2365	4.84	5.16	0.94	100	100

APPENDIX J Raw heart rate data obtained from referee's subject group during match analysis through use of the Polar Vantage NV monitor.

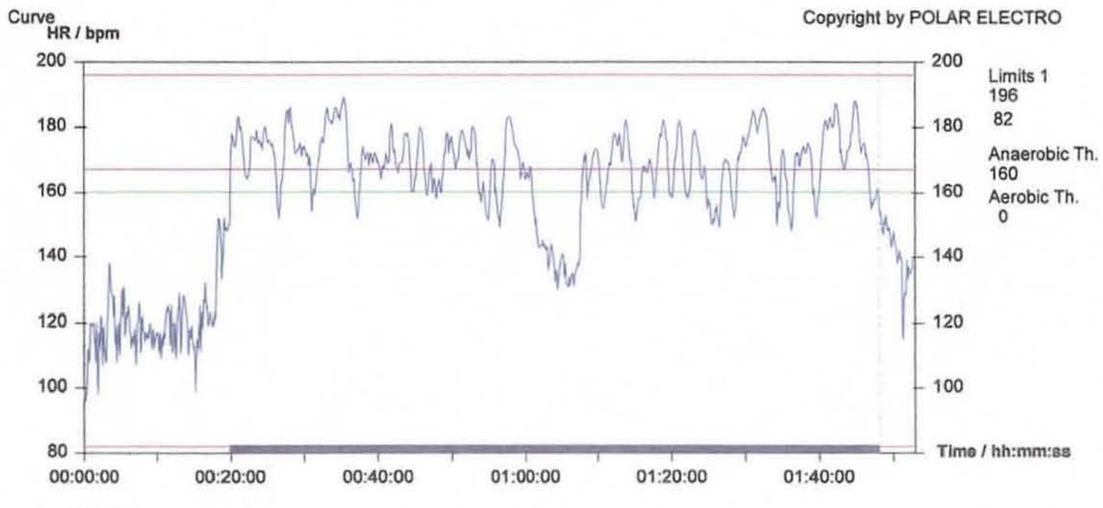
SUBJECT - 1



HR: 142
Time: 01:54:40.0

Person		Date	05/10/1996	Average	161 bpm	Recovery	-17
Exercise	1996/10/05 14:29:26	Time	14:29:26	Duration of exercise: 02:00:47.4			
Note	Northampton v Sale			Selected period is: 00:30:00 - 01:54:40 (01:24:40)			

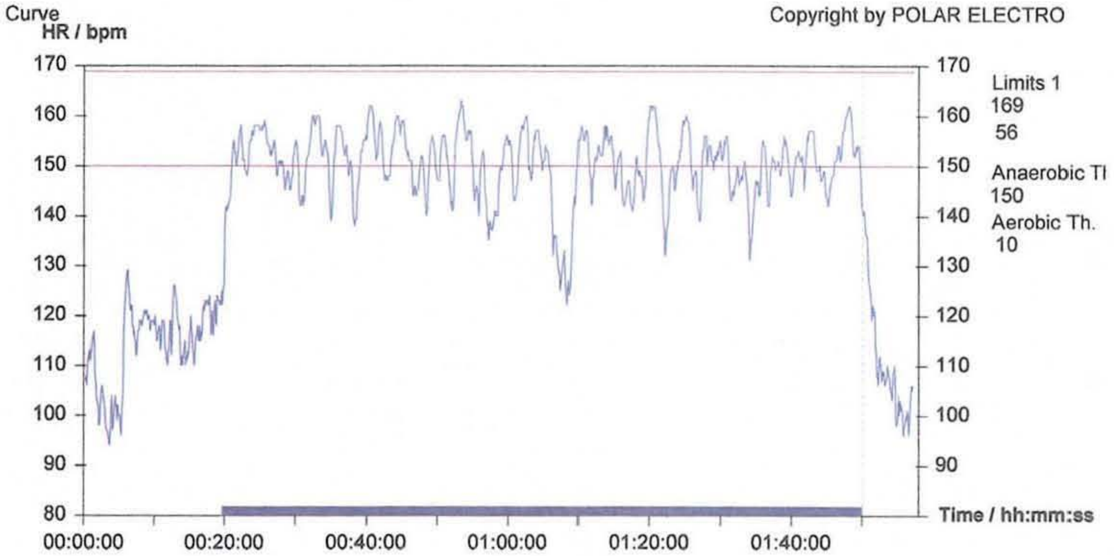
SUBJECT - 2



HR: 157
Time: 01:48:05.0

Person		Date	05/11/1996	Average	167 bpm	Recovery	-7
Exercise	1996/11/05 15:41:39	Time	15:41:39	Duration of exercise: 01:52:41.0			
Note	Oxford Uni v South Africa A			Selected period is: 00:19:45 - 01:48:05 (01:28:20)			

SUBJECT - 3

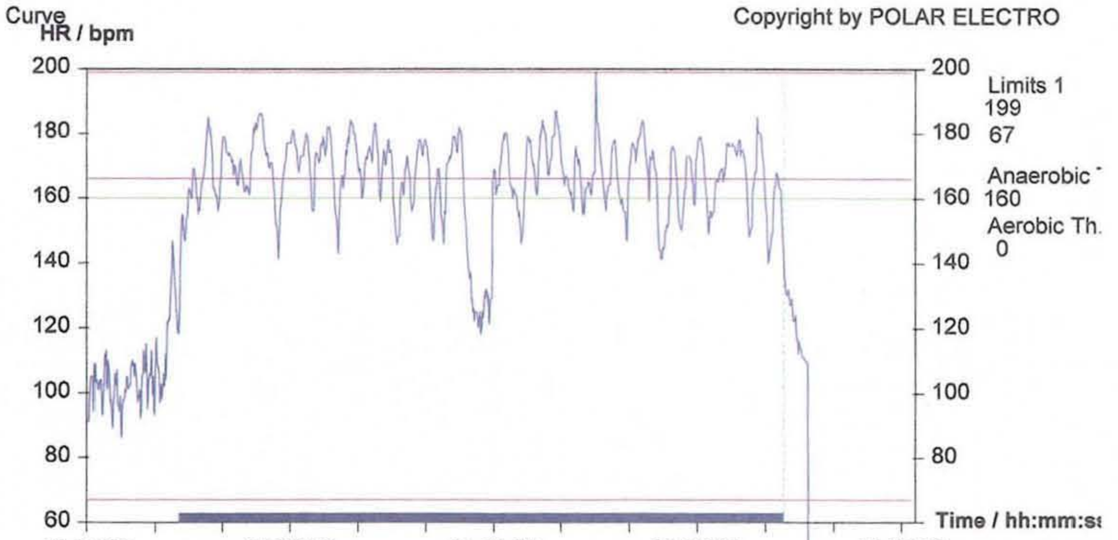


HR: 142

Time: 01:50:00.0

Person	[redacted]	Date	26/10/1996	Average	150 bpm	Recovery	-20
Exercise	1996/10/26 14:36:33	Time	14:36:33	Duration of exercise: 01:57:17.7			
Note	Rotherham v Coventry			Selected period is: 00:19:40 - 01:50:00 (01:30:			

SUBJECT - 4

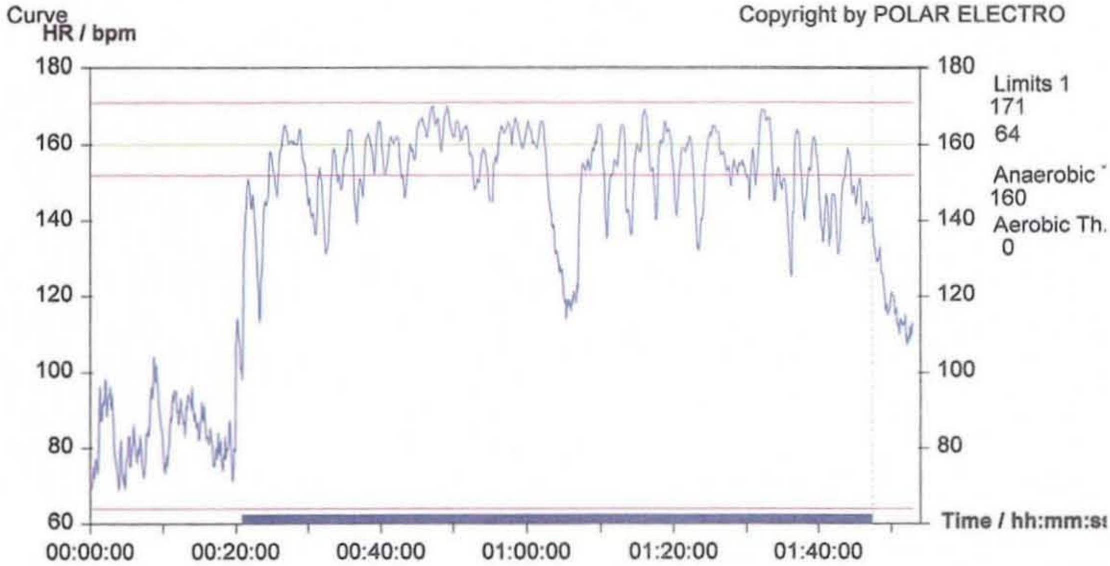


HR: 146

Time: 01:42:35.0

Person	[redacted]n	Date	04/11/1996	Average	166 bpm	Recovery	-27
Exercise	1996/11/04 20:15:01	Time	20:15:01	Duration of exercise: 02:01:21.5			
Note	Bedford v South Africa			Selected period is: 00:13:35 - 01:42:35 (0			

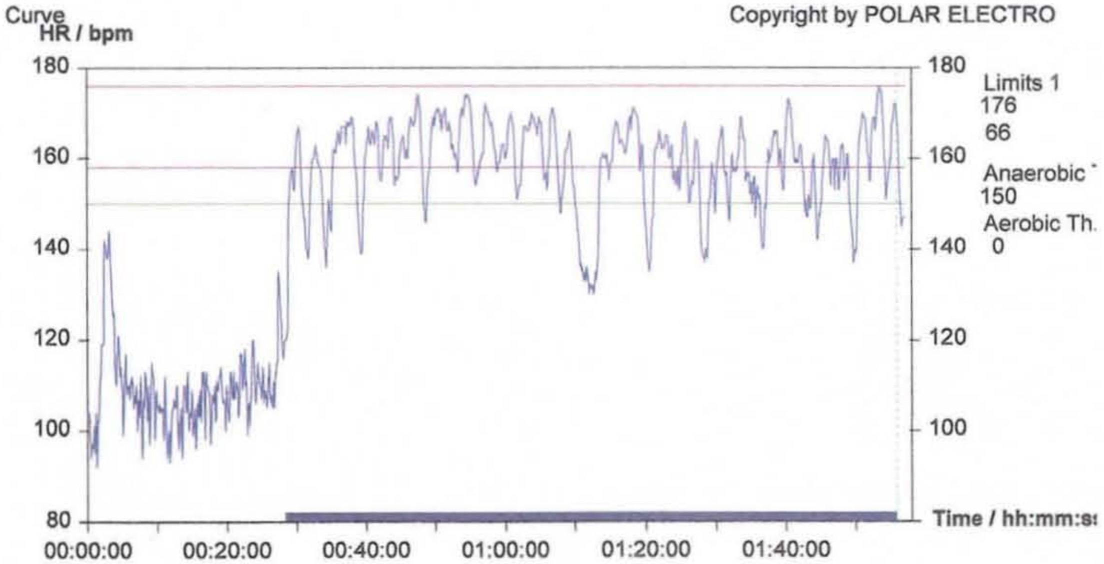
SUBJECT - 5



HR: 140
Time: 01:47:20.0

Person	[redacted]n	Date	16/10/1996	Average	152 bpm	Recovery	-38
Exercise	1996/10/16 19:05:49	Time	19:05:49	Duration of exercise: 01:53:02.3			
Note	Northampton V Orrell			Selected period is: 00:20:50 - 01:47:20 (0			

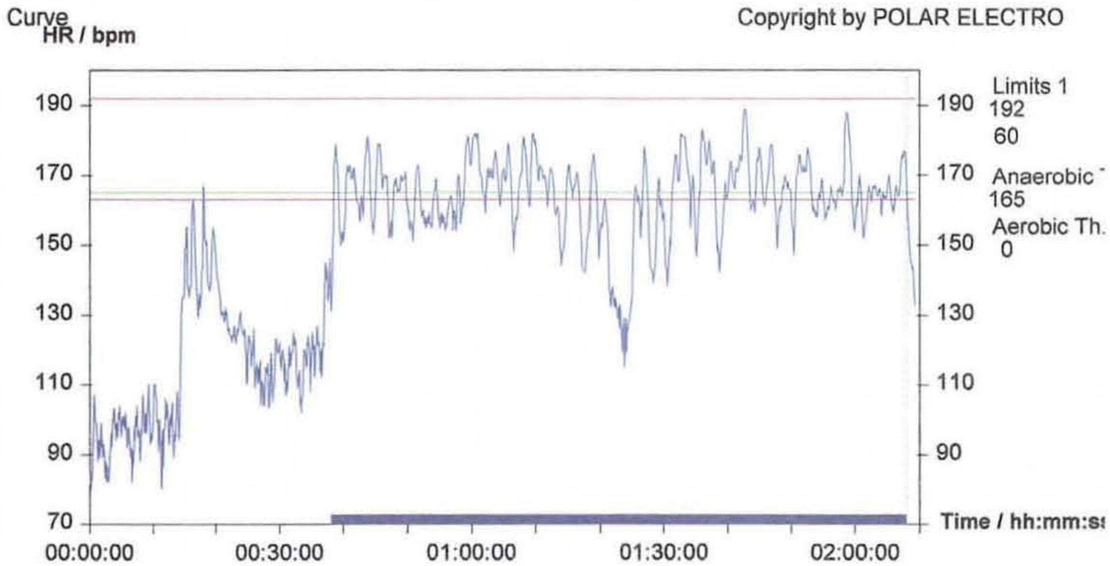
SUBJECT - 6



HR: 172
Time: 01:55:45.0

Person	[redacted]e	Date	08/02/1997	Average	158 bpm	Recovery	-52
Exercise	1997/02/08 14:31:53	Time	14:31:53	Duration of exercise: 01:57:05.8			
Note	Harlequins v Sale			Selected period is: 00:28:20 - 01:55:45 (0			

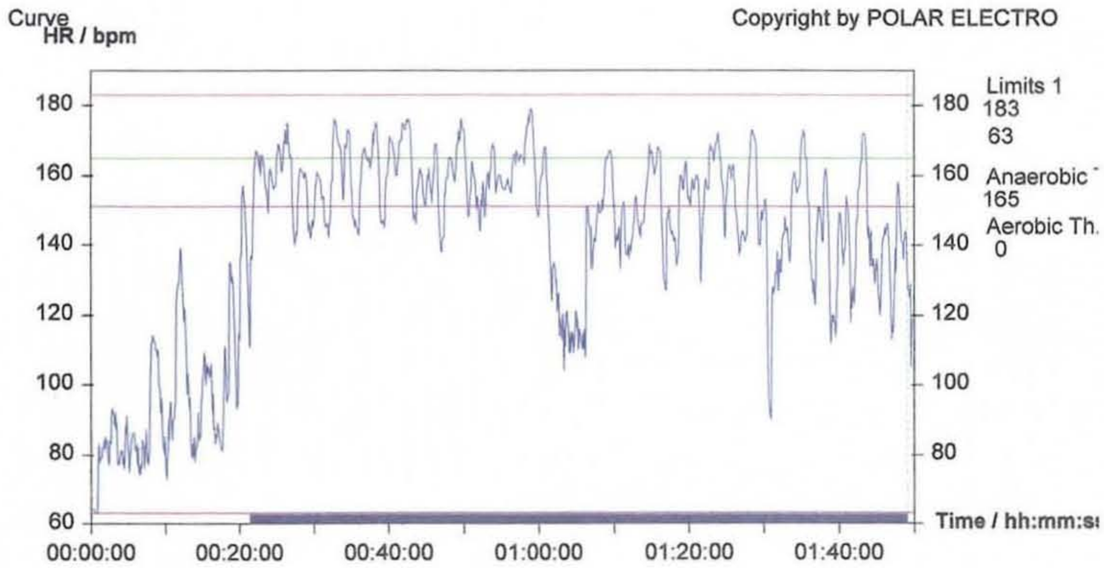
SUBJECT - 7



HR: 172
Time: 02:07:55.0

Person	[redacted]	Date	23/02/1997	Average	163 bpm	Recovery	-41
Exercise	1997/02/23 15:20:51	Time	15:20:51	Duration of exercise: 02:09:17.5			
Note	Harlequins v Saracens			Selected period is: 00:38:00 - 02:07:55 (0			

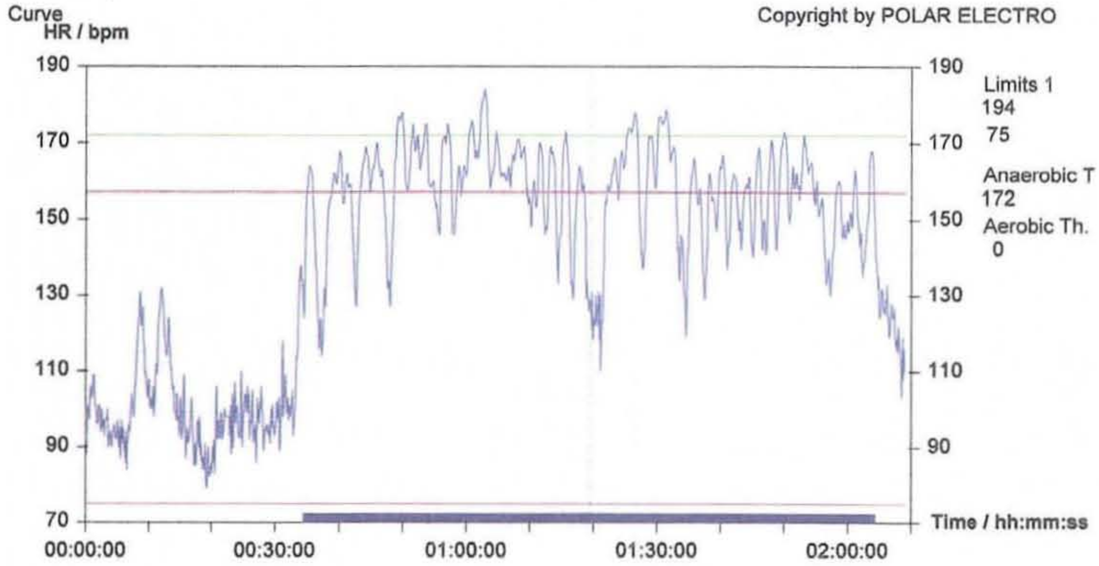
SUBJECT - 8



HR: 136
Time: 01:49:00.0

Person	[redacted]	Date	22/02/1997	Average	151 bpm	Recovery	-25
Exercise	1997/02/22 15:38:54	Time	15:38:54	Duration of exercise: 01:49:46.6			
Note	London Scottish v Ystradgynlais			Selected period is: 00:21:20 - 01:49:00 (0			

SUBJECT - 9

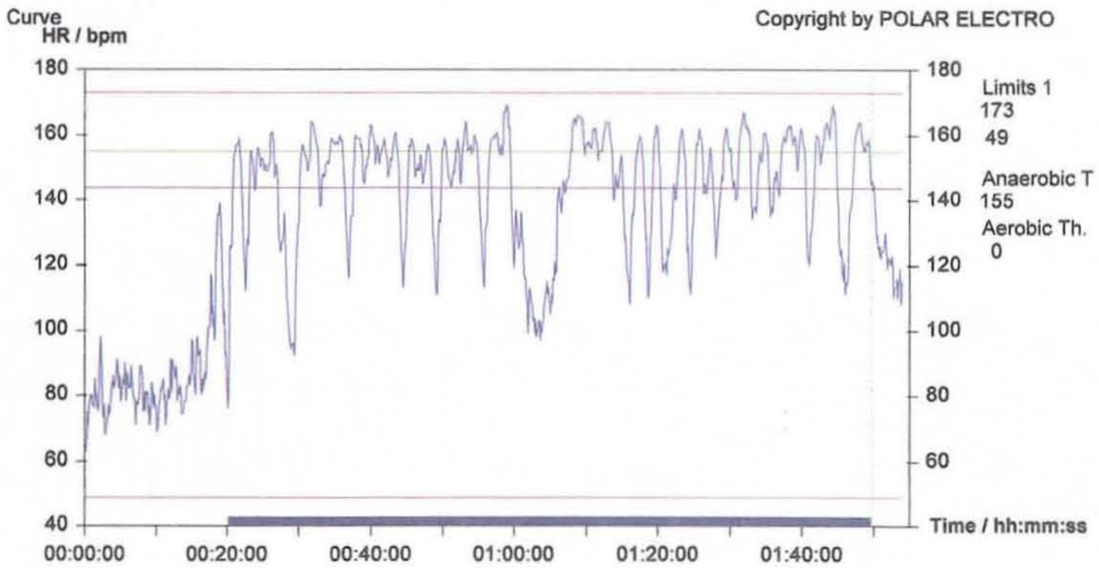


HR: 129

Time: 01:19:25.0

Person	[redacted]	Date	07/12/1996	Average	157 bpm	Recovery	-19
Exercise	1996/12/07 14:26:48	Time	14:26:48	Duration of exercise: 02:08:55.2			
Note	Orrell v West Hartlepool			Selected period is: 00:34:30 - 02:04:20 (01:29			

SUBJECT - 10



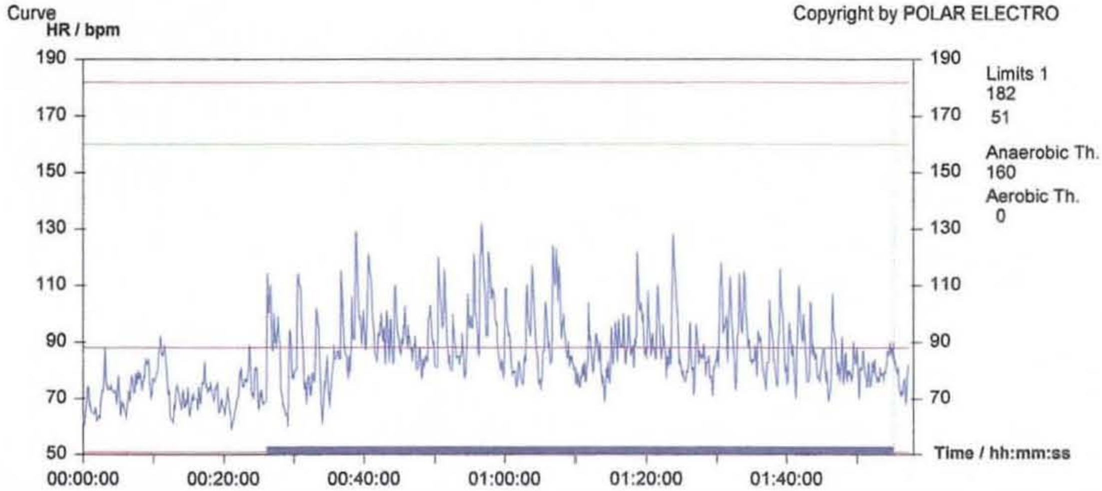
HR: 145

Time: 01:49:35.0

Person	[redacted]	Date	22/03/1997	Average	144 bpm	Recovery	-69
Exercise	1997/03/22 15:38:19	Time	15:38:19	Duration of exercise: 01:53:58.5			
Note	Bristol v Sale			Selected period is: 00:20:10 - 01:49:35 (01:29			

APPENDIX K Raw heart rate data obtained from touch-judges's subject group during match analysis through use of the Polar Vantage NV monitor.

SUBJECT - 1

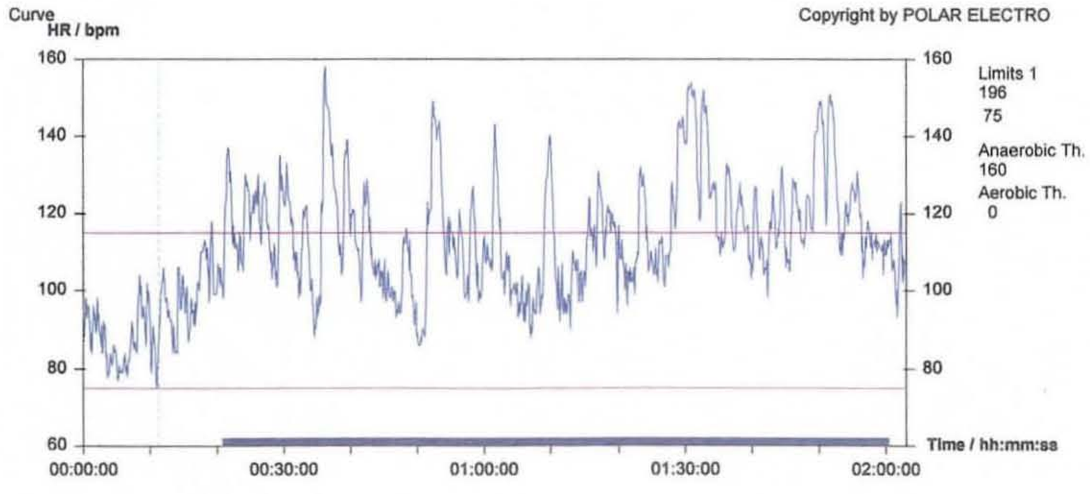


HR: 90

Time: 01:55:10.0

Person		Date	11/02/1997	Average	88 bpm	Recovery	-21
Exercise	1997/02/11 19:02:26	Time	19:02:26	Duration of exercise: 01:57:17.5			
Note	Leicester/Northampton v Otago			Selected period is: 00:26:00 - 01:55:10 (01:29:10)			

SUBJECT - 2

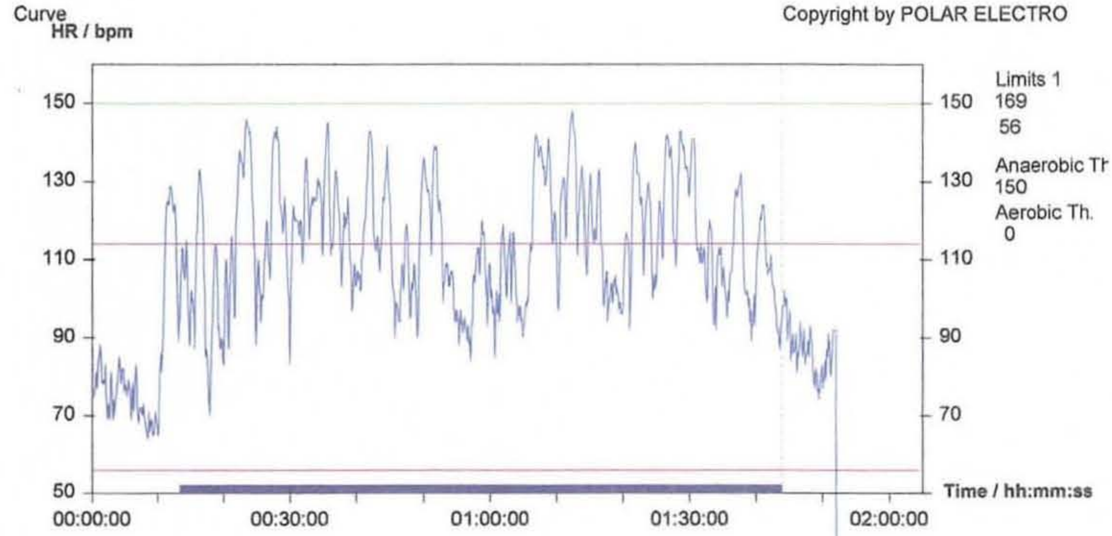


HR: 86

Time: 00:11:15.0

Person		Date	29/10/1997	Average	115 bpm	Recovery	-11
Exercise	1997/10/29 08:12:12 PM	Time	20:12:12	Duration of exercise: 02:02:40.6			
Note	Bristol v Tonga - touch			Selected period is: 00:20:45 - 02:00:25 (01:39:40)			

SUBJECT - 3

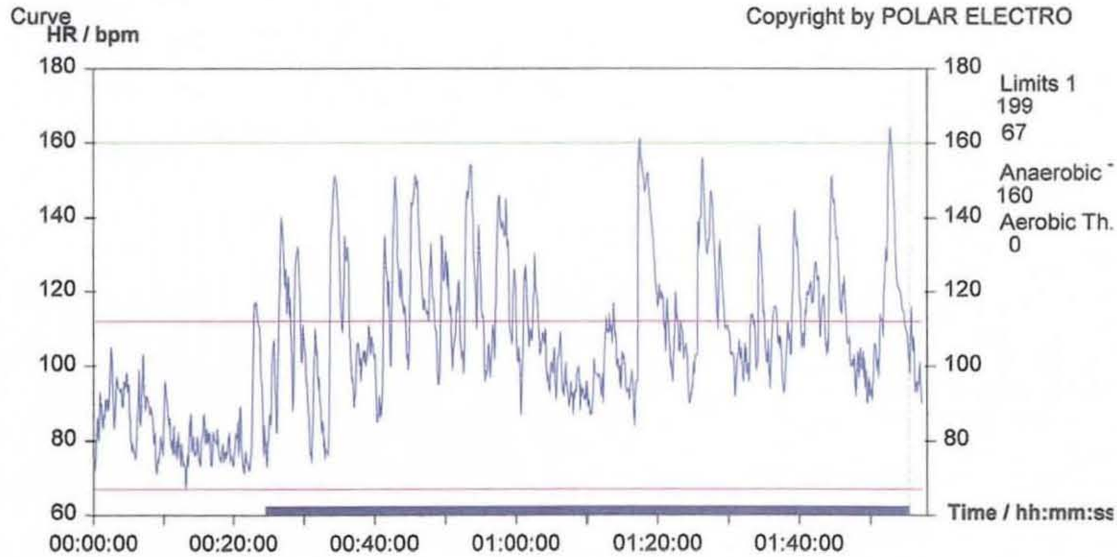


HR: 95

Time: 01:43:55.0

Person	[redacted]	Date	04/11/1996	Average	114 bpm	Recovery	-1
Exercise	1996/11/04 20:16:15	Time	20:16:15	Duration of exercise: 02:04:24.9			
Note	Bedford v South Africa A - touch			Selected period is: 00:13:15 - 01:43:55 (01:30:40			

SUBJECT - 4

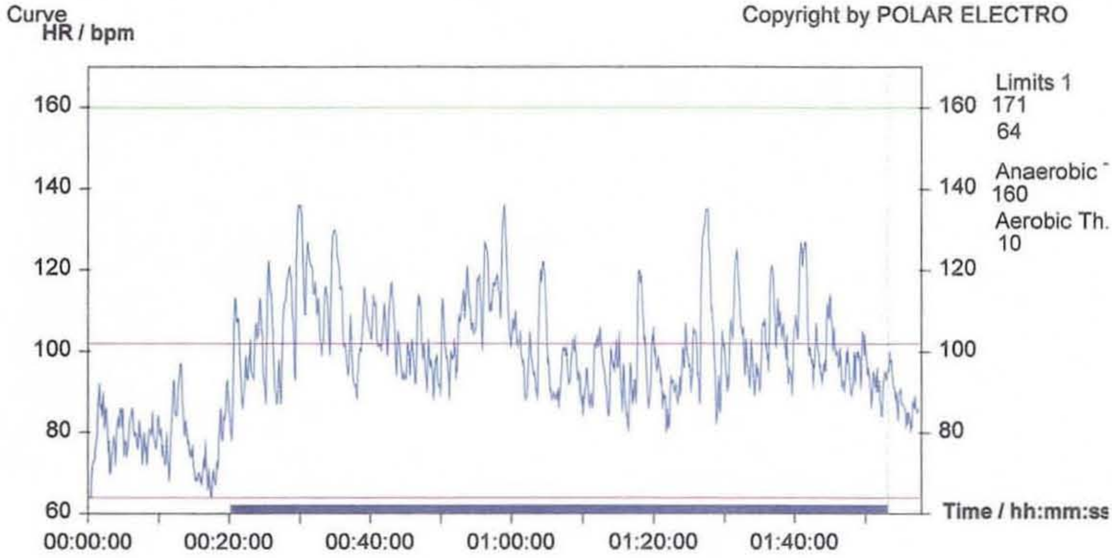


HR: 102

Time: 01:55:30.0

Person	[redacted]	Date	16/11/1996	Average	112 bpm	Recovery	-22
Exercise	1996/11/16 15:34:08	Time	15:34:08	Duration of exercise: 01:57:15.2			
Note	Oxford Uni v South Africa A - touch			Selected period is: 00:24:30 - 01:55:30 (01			

SUBJECT - 5

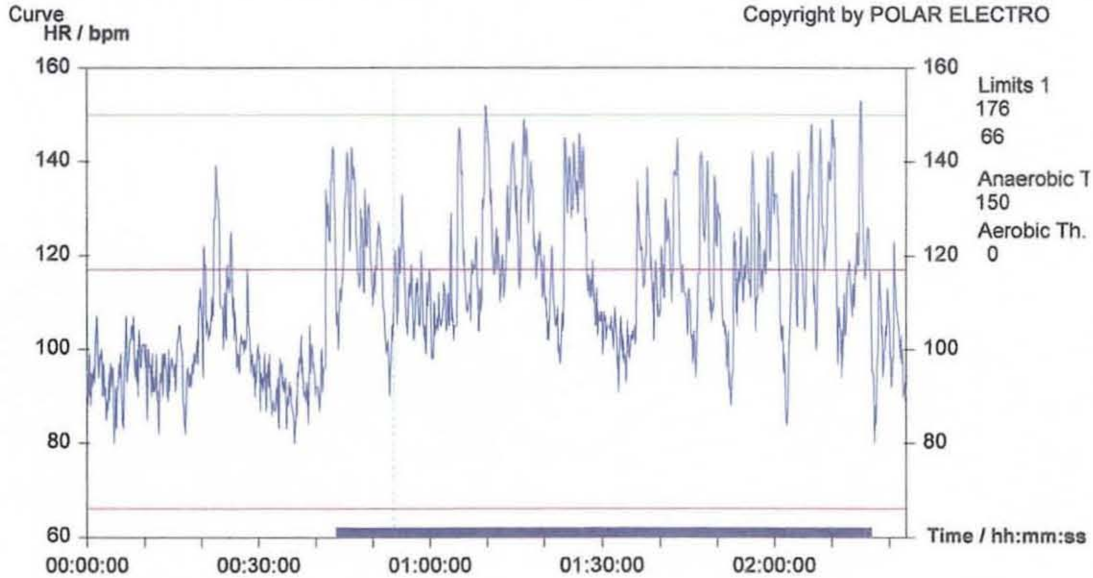


HR: 95

Time: 01:53:10.0

Person	[redacted]	Date	04/01/1997	Average	102 bpm	Recovery	-15
Exercise	1997/01/04 14:37:07	Time	14:37:07	Duration of exercise: 01:57:36.9			
Note	West Hartlepool v Bristol - touch			Selected period is: 00:20:10 - 01:53:10 (01			

SUBJECT - 6

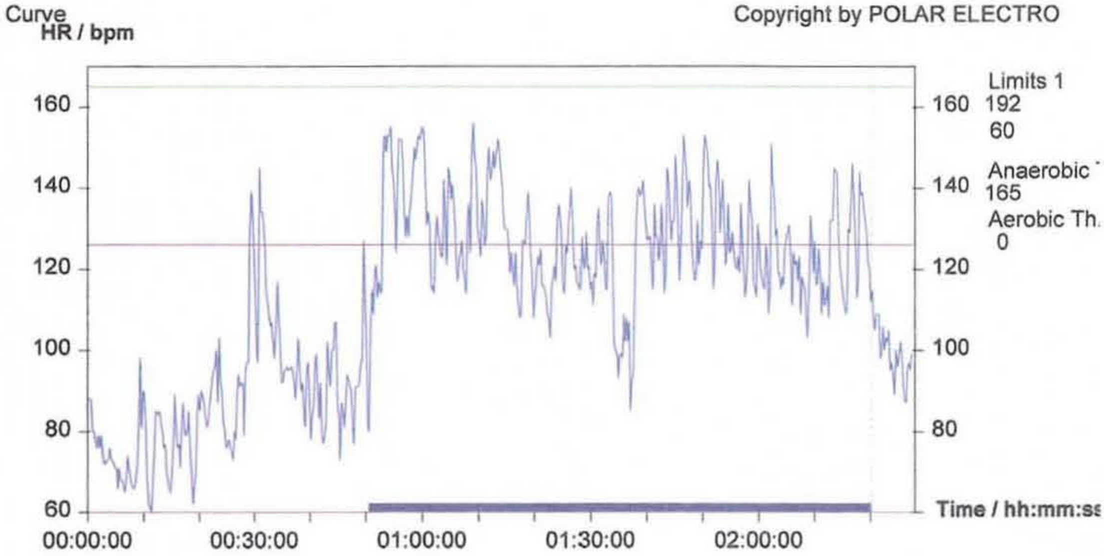


HR: 105

Time: 00:53:35.0

Person	[redacted]	Date	17/06/1995	Average	117 bpm	Recovery	11
Exercise	1995/06/17 08:44:11	Time	8:44:11	Duration of exercise: 02:22:51.7			
Note	Bath v Northampton - touch judge			Selected period is: 00:43:30 - 02:16:55 (01:3			

SUBJECT - 7

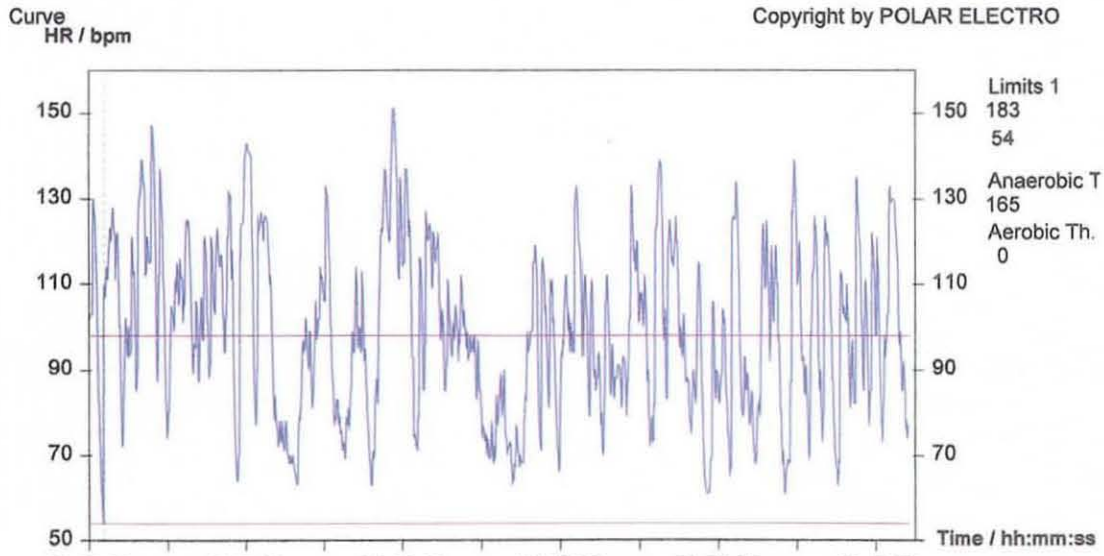


HR: 112

Time: 02:20:00.0

Person	[redacted]r	Date	21/12/1996	Average	126 bpm	Recovery	-32
Exercise	1996/12/21 13:14:13	Time	13:14:13	Duration of exercise: 02:27:24.7			
Note	Sale v Richmond - touch			Selected period is: 00:50:30 - 02:20:00 (0			

SUBJECT - 8

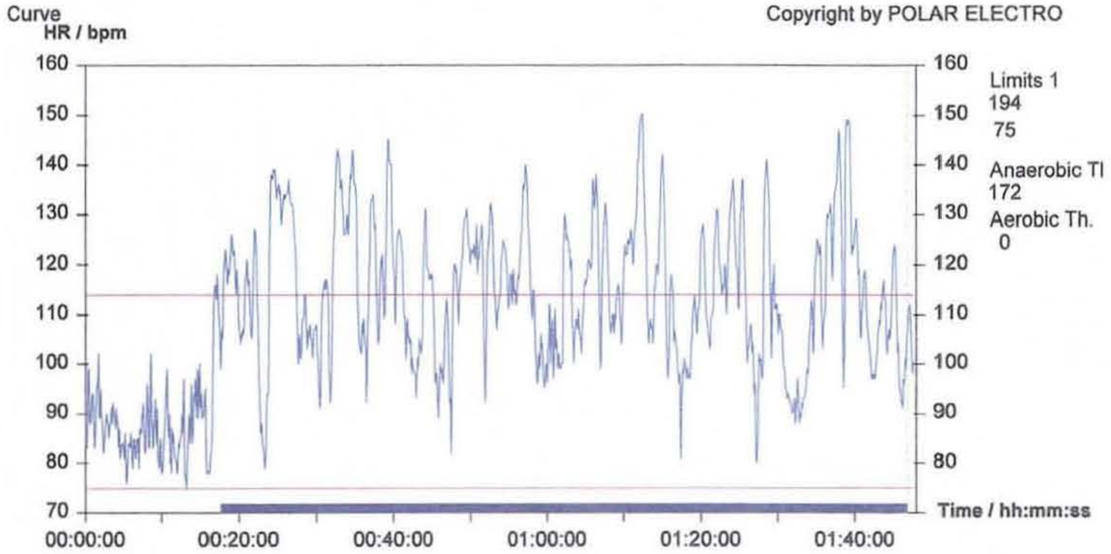


HR: 110

Time: 00:01:45.0

Person	[redacted]	Date	22/03/1995	Average	98 bpm	Recovery	0
Exercise	1995/03/22 3:00:00	Time	8:18:09	Duration of exercise: 01:44:04.8			
Note	Wakefield v Moseley - touch judge						

SUBJECT - 9

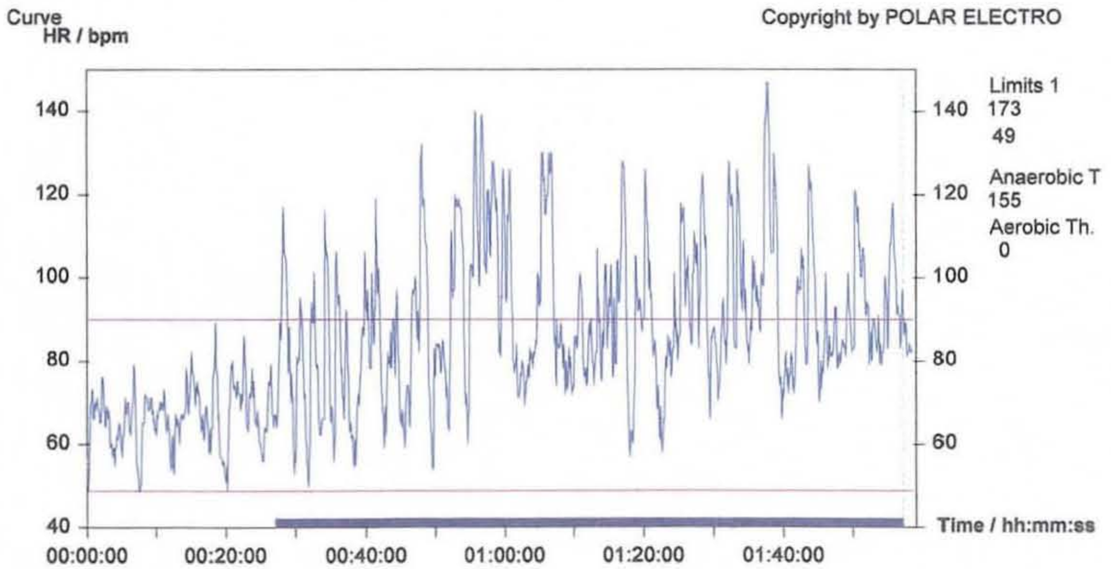


HR: 106

Time: 01:46:50.0

Person		Date	15/04/1997	Average	114 bpm	Recovery	-7
Exercise	1997/04/15 18:55:02	Time	18:55:02	Duration of exercise: 01:47:37.1			
Note	Sale v Saracens - touch			Selected period is: 00:17:35 - 01:46:50 (01:29:			

SUBJECT - 10



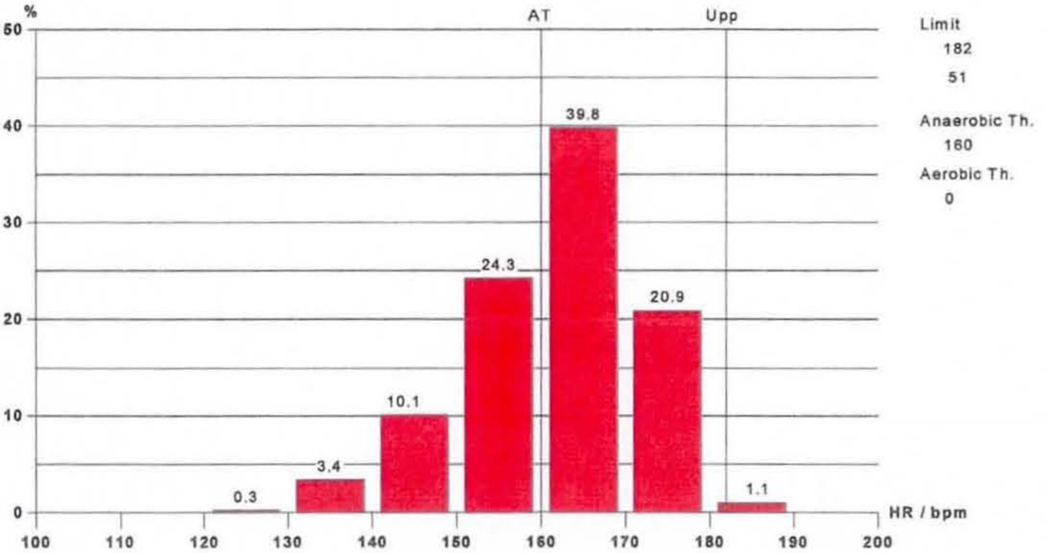
HR: 92

Time: 01:57:10.0

Person		Date	29/03/1997	Average	90 bpm	Recovery	-26
Exercise	1997/03/29 15:30:24	Time	15:30:24	Duration of exercise: 01:58:28.9			
Note	Orrell v Northampton - touch			Selected period is: 00:27:00 - 01:57:10 (01:30:			

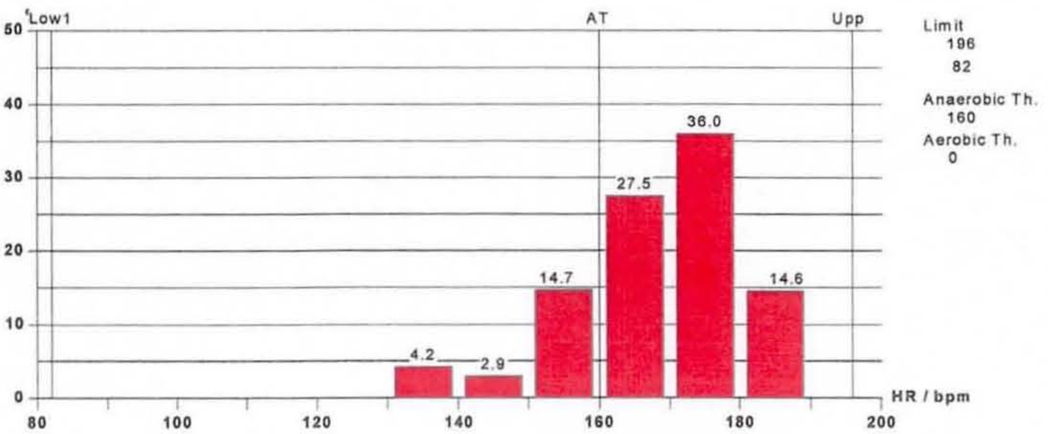
APPENDIX L Percentage distribution of heart rate data obtained from referees' subject group during match analysis through use of the Polar Vantage NV monitor.

SUBJECT - 1



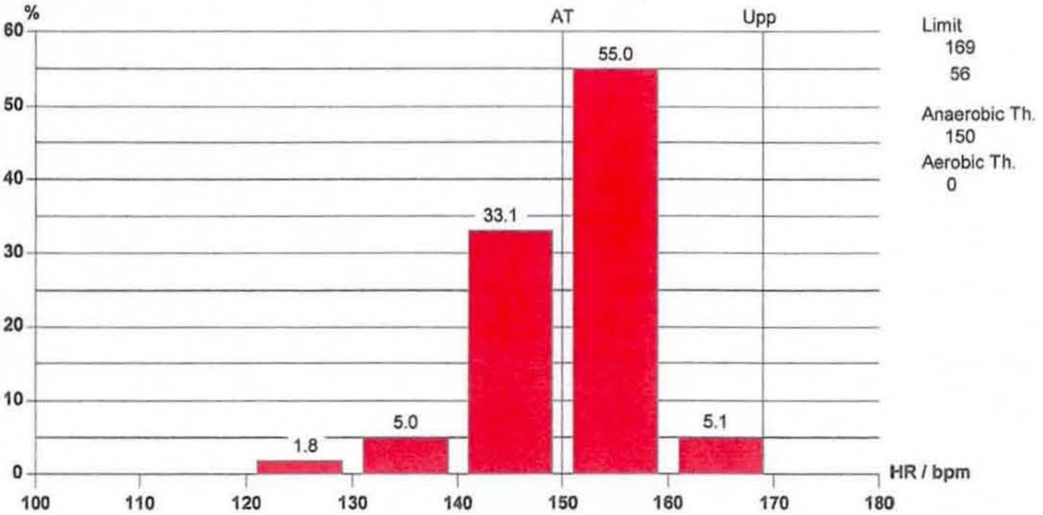
Person		Date	05/10/1996	Duration of exercise: 02:00:47.4
Exercise	1996/10/05 14:29:26	Time	14:29:26	Selected period is: 00:30:00 - 01:54:40
Note	Northampton v Sale			

SUBJECT - 2



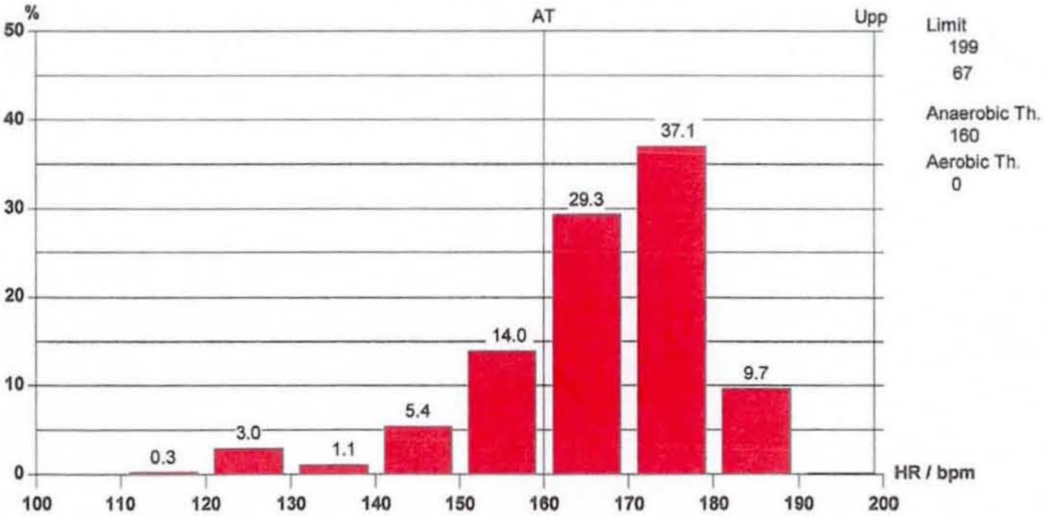
Person		Date	05/11/1996	Duration of exercise: 01:52:41.0
Exercise	1996/11/05	Time	15:41:39	Selected period is: 00:19:45 - 01:48:05
Note	Oxford Uni v South Africa A			

SUBJECT - 3



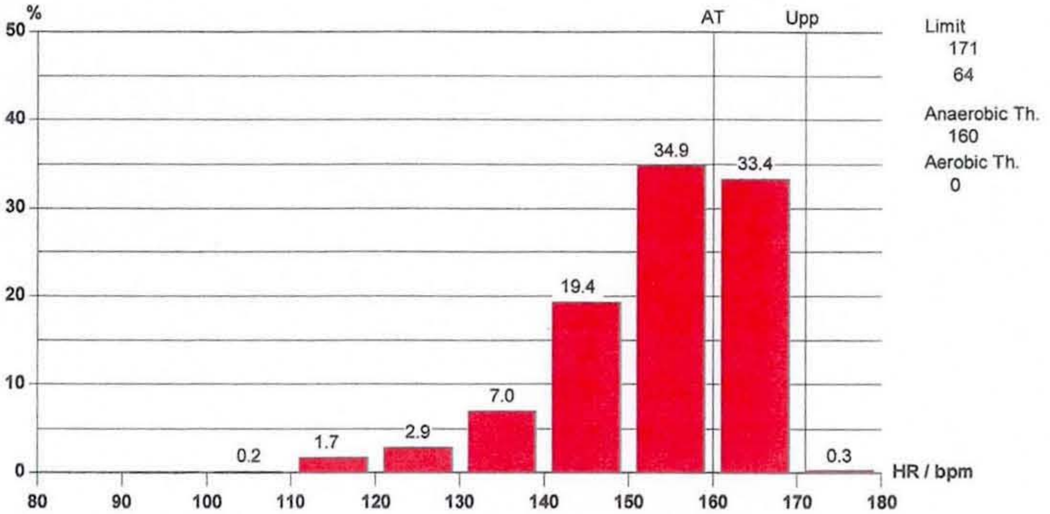
Person		Date	26/10/1996	Duration of exercise: 01:57:17.7
Exercise	1996/10/26 14:36:33	Time	14:36:33	Selected period is: 00:19:50 - 01:49:55
Note	Rotherham v Coventry			

SUBJECT - 4



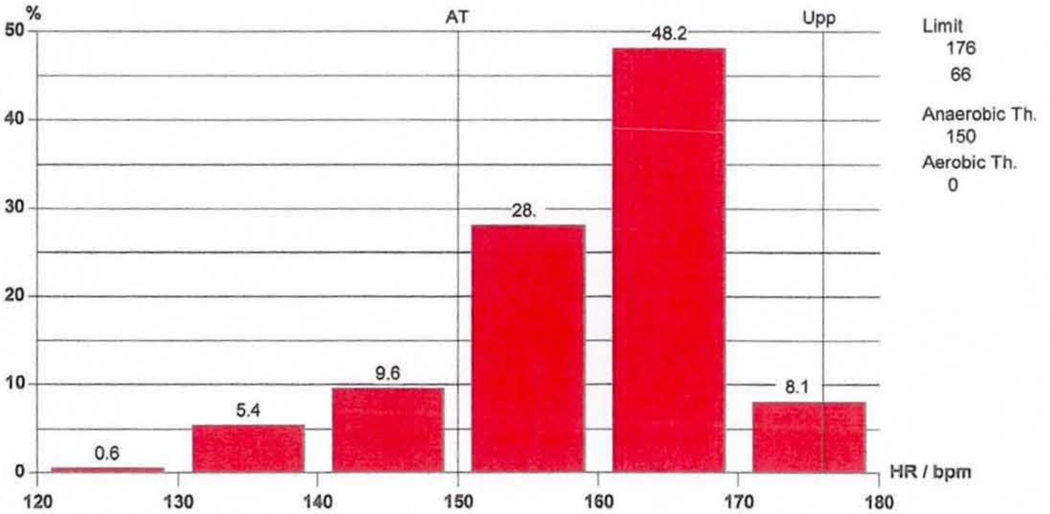
Person		Date	04/11/1996	Duration of exercise: 02:01:21.5
Exercise	1996/11/04	Time	20:15:01	Selected period is: 00:13:25 - 01:42:20
Note	Bedford v South Africa			

SUBJECT - 5



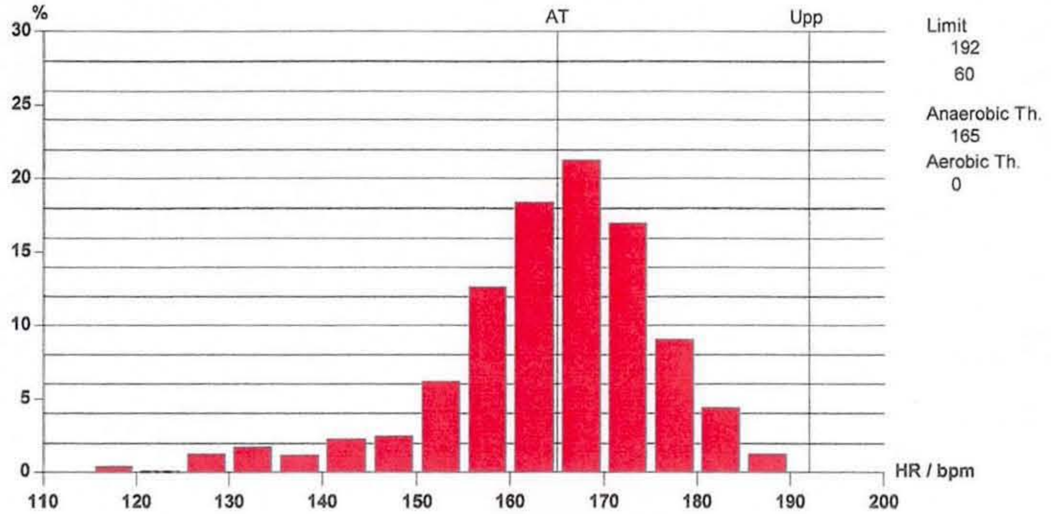
Person		Date	16/10/1996	Duration of exercise: 01:53:02.3
Exercise	1996/10/16 19:05:49	Time	19:05:49	Selected period is: 00:20:50 - 01:47:20
Note	Northampton V Orrell			

SUBJECT - 6



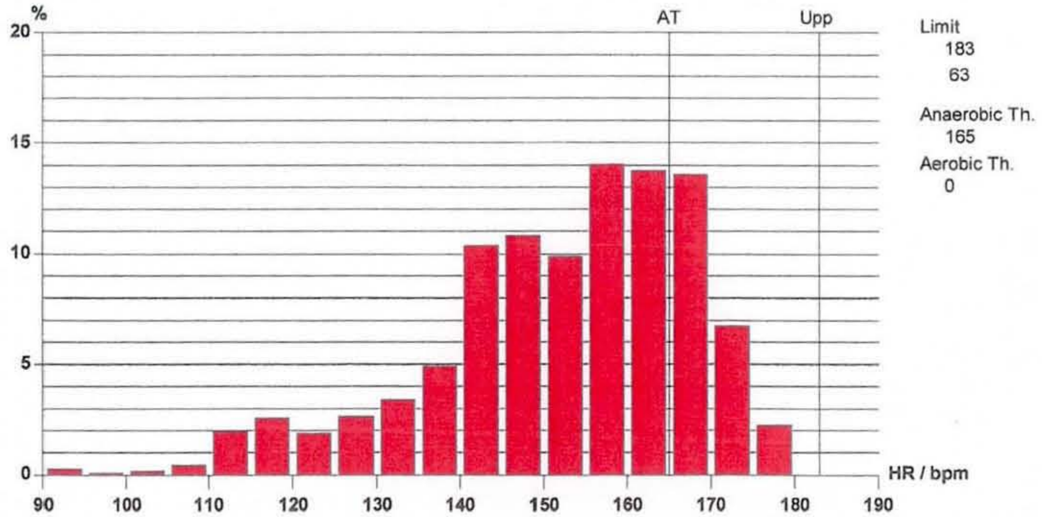
Person		Date	08/02/1997	Duration of exercise: 01:57:05.8
Exercise	1997/02/08 14:31:53	Time	14:31:53	Selected period is: 00:28:20 - 01:55:45
Note	Harlequins v Sale			

SUBJECT - 7



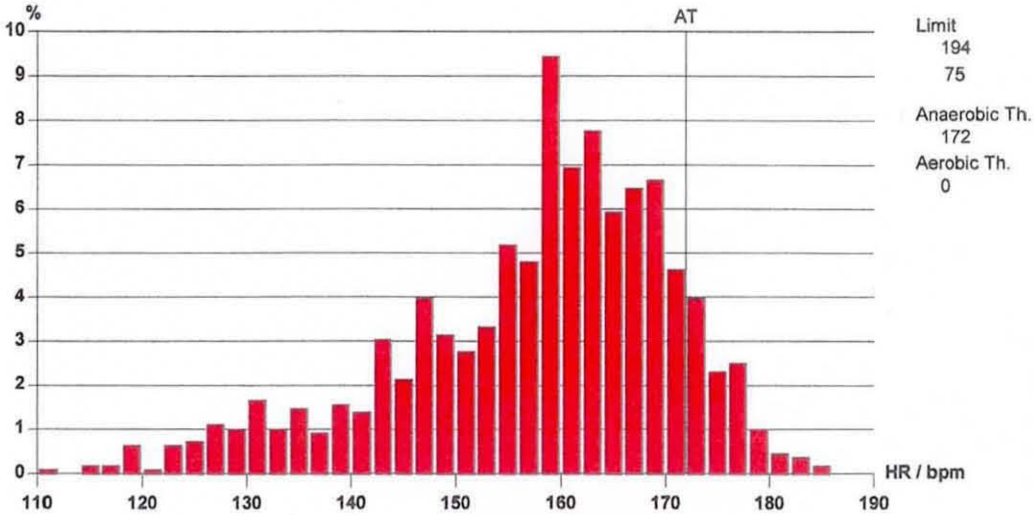
Person		Date	23/02/1997	Duration of exercise: 02:09:17.5
Exercise	1997/02/23 15:20:51	Time	15:20:51	Selected period is: 00:38:00 - 02:07:55
Note	Harlequins v Saracens			

SUBJECT - 8



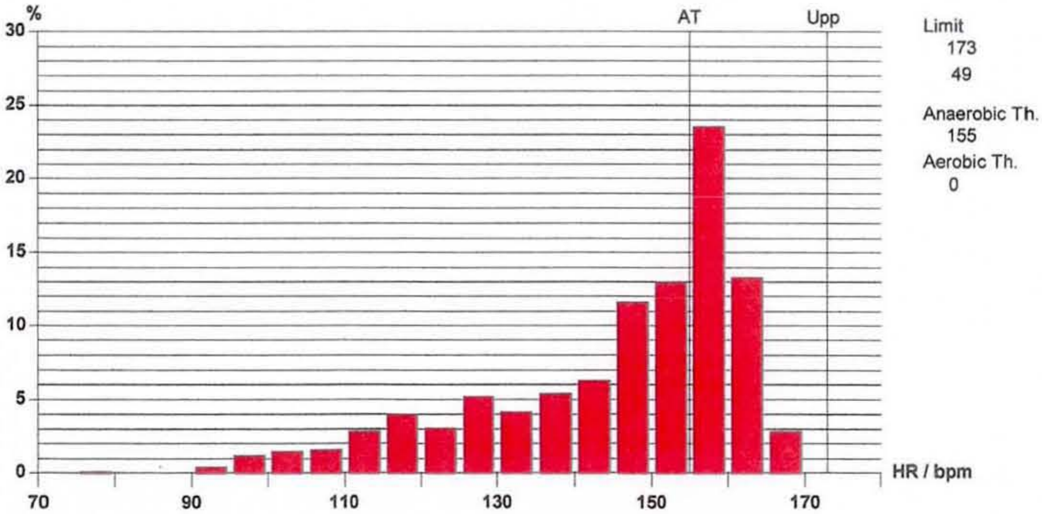
Person		Date	22/02/1997	Duration of exercise: 01:49:46.6
Exercise	1997/02/22 15:38:54	Time	15:38:54	Selected period is: 00:21:20 - 01:49:00
Note	London Scottish v Ystradgynlais			

SUBJECT - 9



Person		Date	07/12/1996	Duration of exercise: 02:08:55.2
Exercise	1996/12/07 14:26:48	Time	14:26:48	Selected period is: 00:34:30 - 02:04:20
Note	Orrell v West Hartlepool			

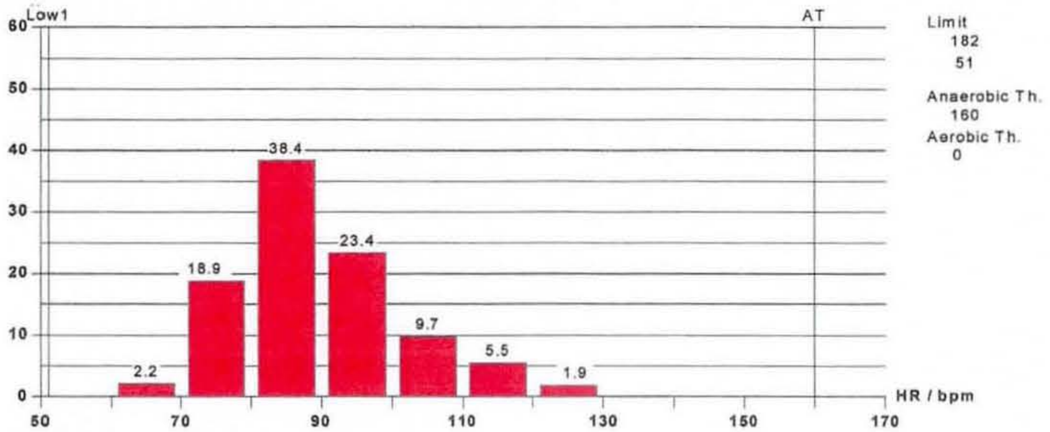
SUBJECT - 10



Person		Date	22/03/1997	Duration of exercise: 01:53:58.5
Exercise	1997/03/22 15:38:19	Time	15:38:19	Selected period is: 00:20:10 - 01:49:35
Note	Bristol v Sale			

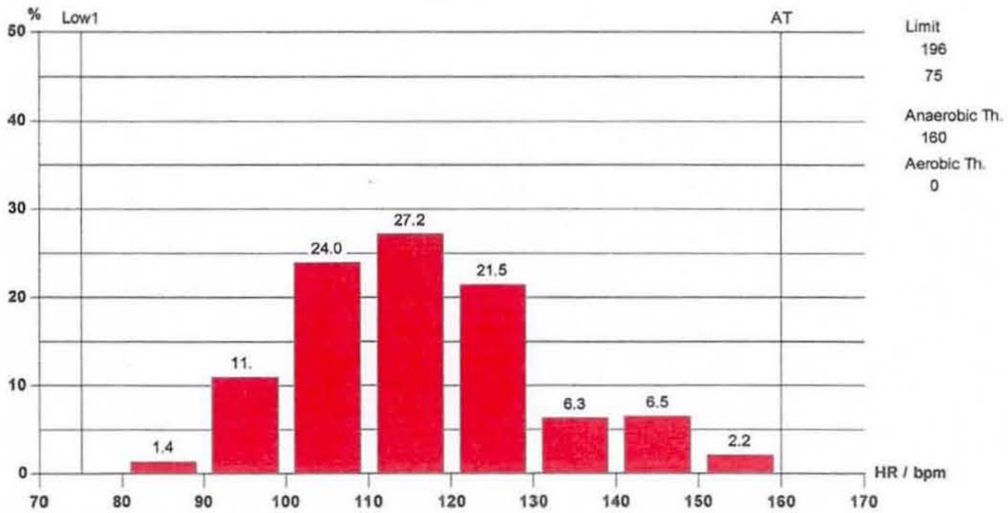
APPENDIX M Percentage distribution of heart rate data obtained from touch judges' subject group during match analysis through use of the Polar Vantage NV monitor.

SUBJECT - 1



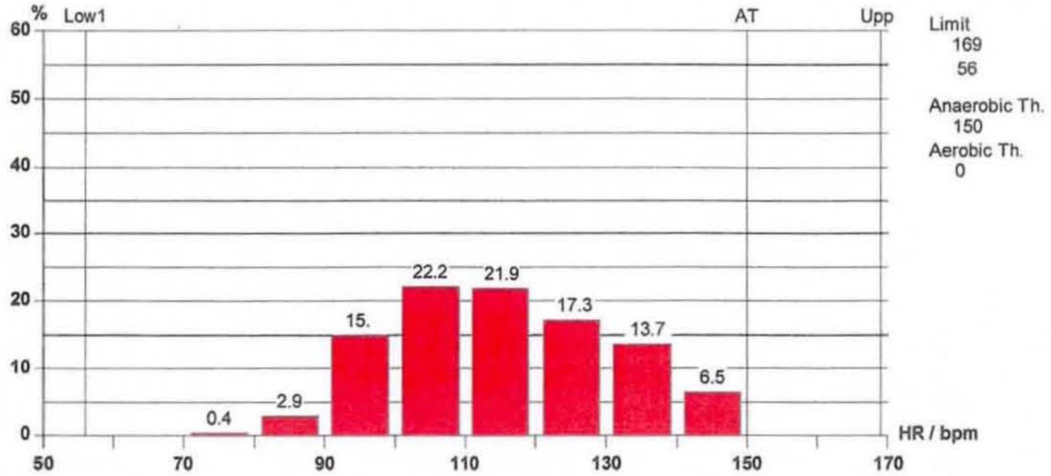
Person		Date	11/02/1997	Duration of exercise: 01:57:17.5
Exercise	1997/02/11 19:02:26	Time	19:02:26	Selected period is: 00:25:55 - 01:54:55
Note	Leicester/Northampton v Otago			

SUBJECT - 2



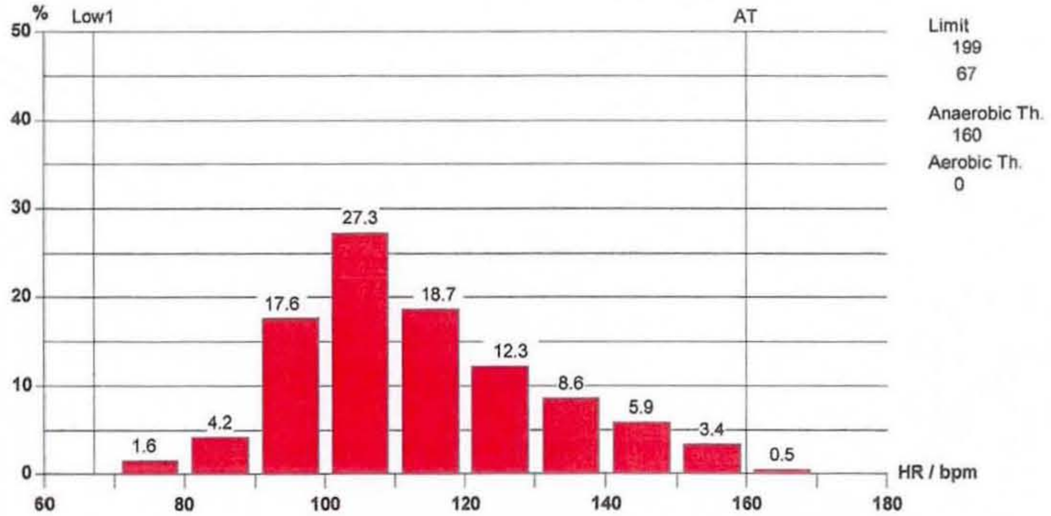
Person		Date	29/10/1997	Duration of exercise: 02:02:40.6
Exercise	1997/10/29 08:12:12 PM	Time	20:12:12	Selected period is: 00:20:45 - 02:00:25
Note	Bristol v Tonga - touch			

SUBJECT - 3



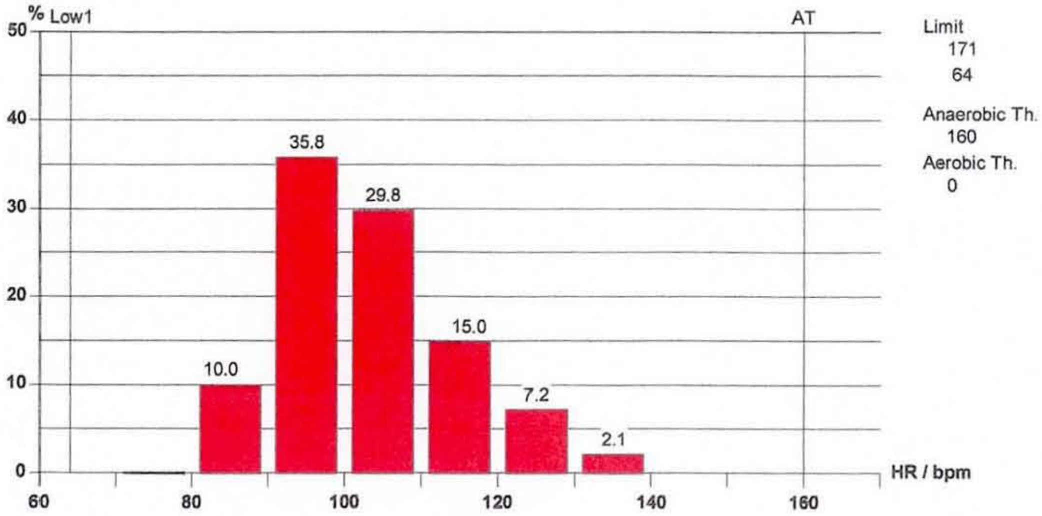
Person		Date	04/11/1996	Duration of exercise: 02:04:24.9
Exercise	1996/11/04 20:16:15	Time	20:16:15	Selected period is: 00:13:15 - 01:43:55
Note	Bedford v South Africa A - touch			

SUBJECT - 4



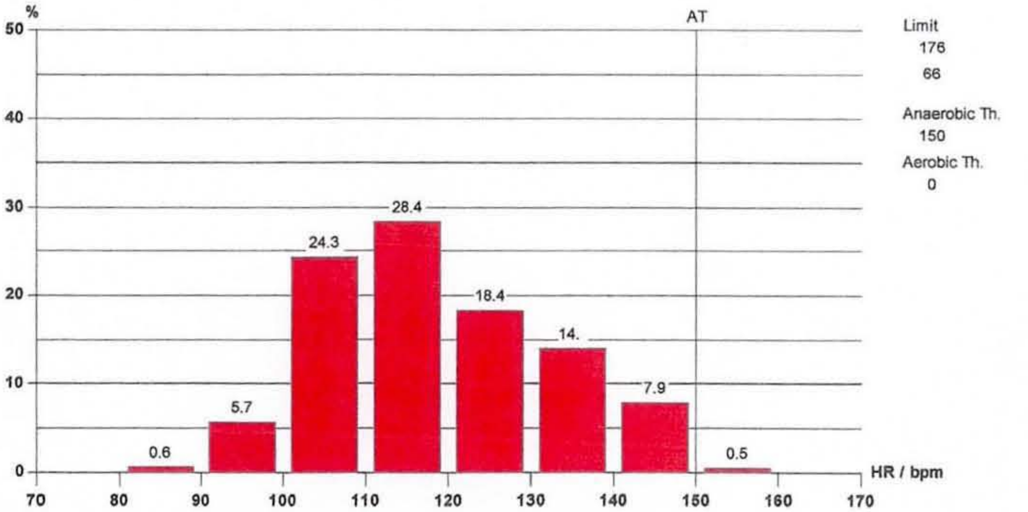
Person		Date	16/11/199	Duration of exercise: 01:57:15.2
Exercise	1996/11/16	Time	15:34:08	Selected period is: 00:24:30 - 01:55:30
Note	Oxford Uni v South Africa A - touch			

SUBJECT - 5



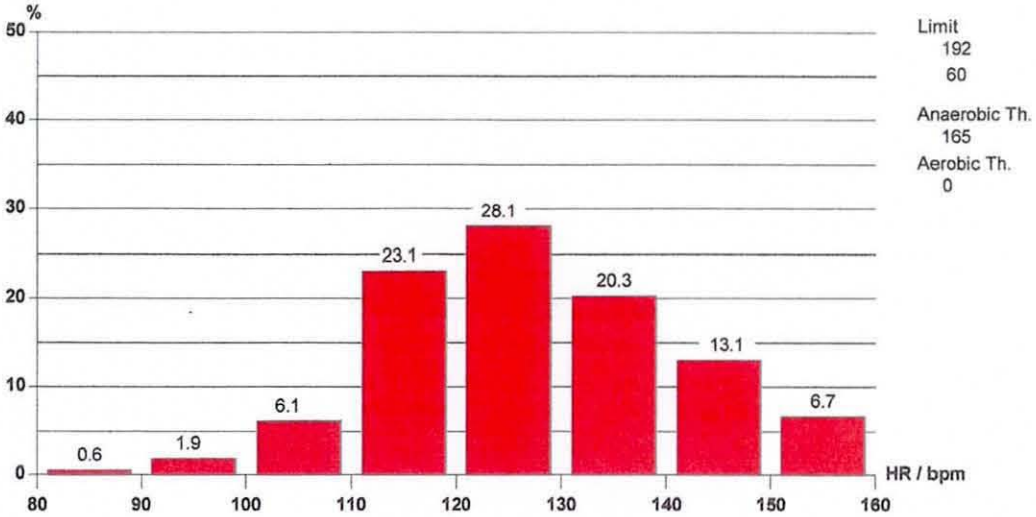
Person		Date	04/01/1997	Duration of exercise: 01:57:36.9
Exercise	1997/01/04 14:37:07	Time	14:37:07	Selected period is: 00:20:10 - 01:53:10
Note	West Hartlepool v Bristol - touch			

SUBJECT - 6



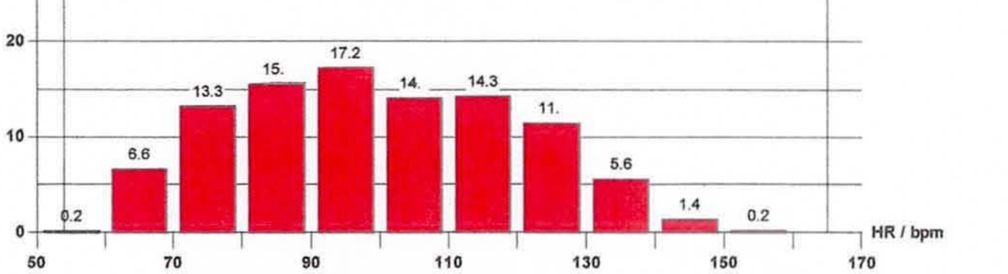
Person		Date	17/06/1995	Duration of exercise: 02:22:51.7
Exercise	1995/06/17 08:44:11	Time	8:44:11	Selected period is: 00:43:30 - 02:16:55
Note	Bath v Northampton - touch judge			

SUBJECT - 7



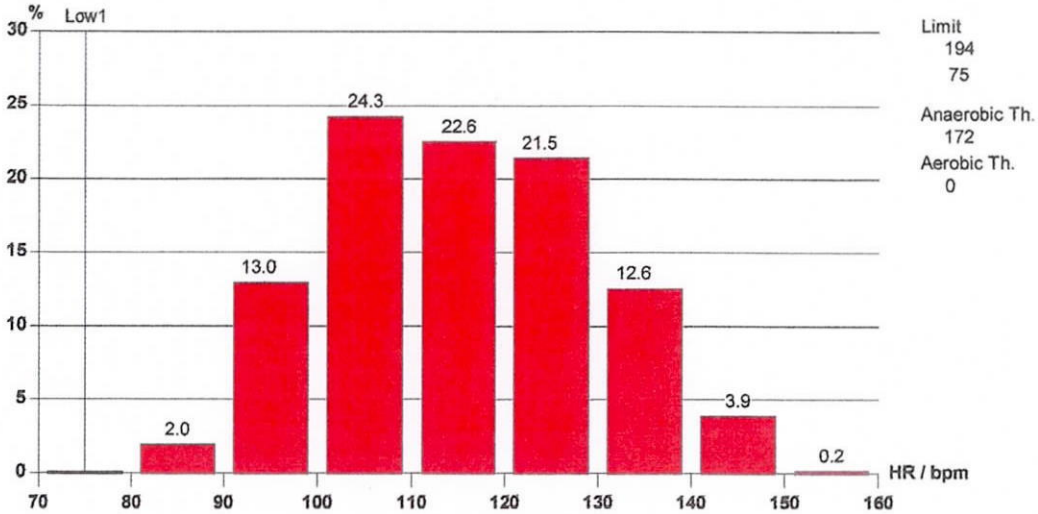
Person		Date	21/12/1996	Duration of exercise: 02:27:24.7
Exercise	1996/12/21	Time	13:14:1	Selected period is: 00:50:30 - 02:20:00
Note	Sale v Richmond - touch			

SUBJECT - 8



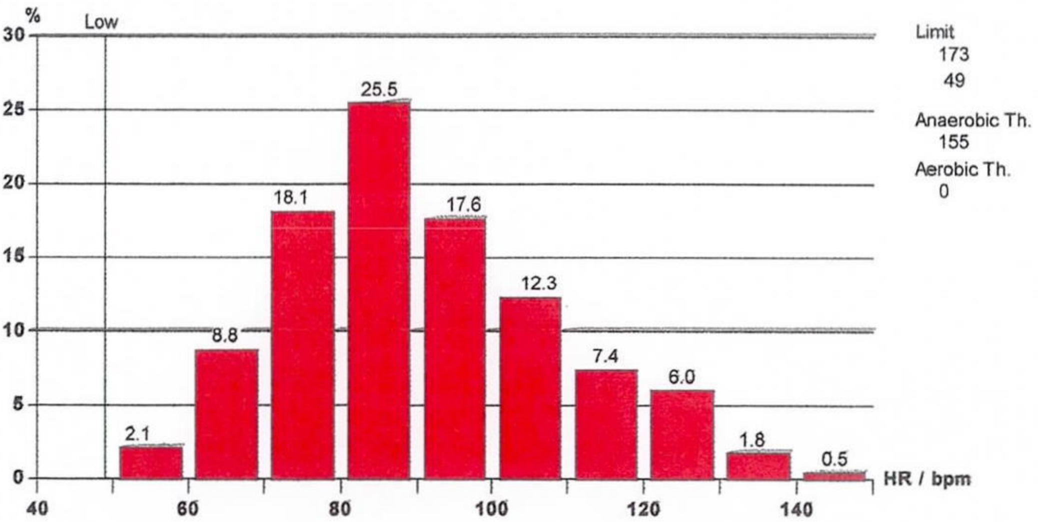
Person		Date	22/03/1995	Duration of exercise: 01:44:04.8
Exercise	1995/03/22 3:00:00	Time	8:18:09	Selected period is: the whole test
Note	Wakefield v Moseley - touch judge			

SUBJECT - 9



Person		Date	15/04/1997	Duration of exercise: 01:47:37.1
Exercise	1997/04/15 18:55:02	Time	18:55:02	Selected period is: 00:17:35 - 01:46:50
Note	Sale v Saracens - touch			

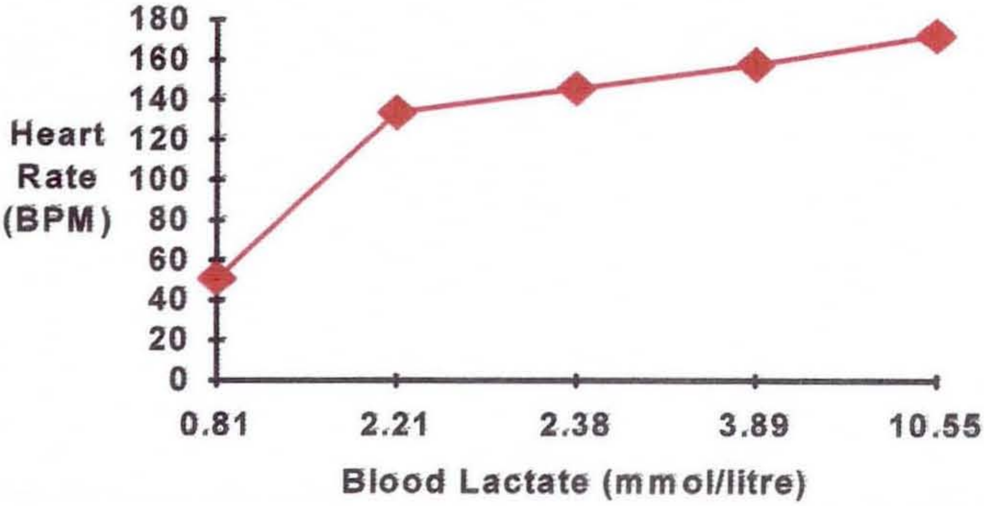
SUBJECT - 10



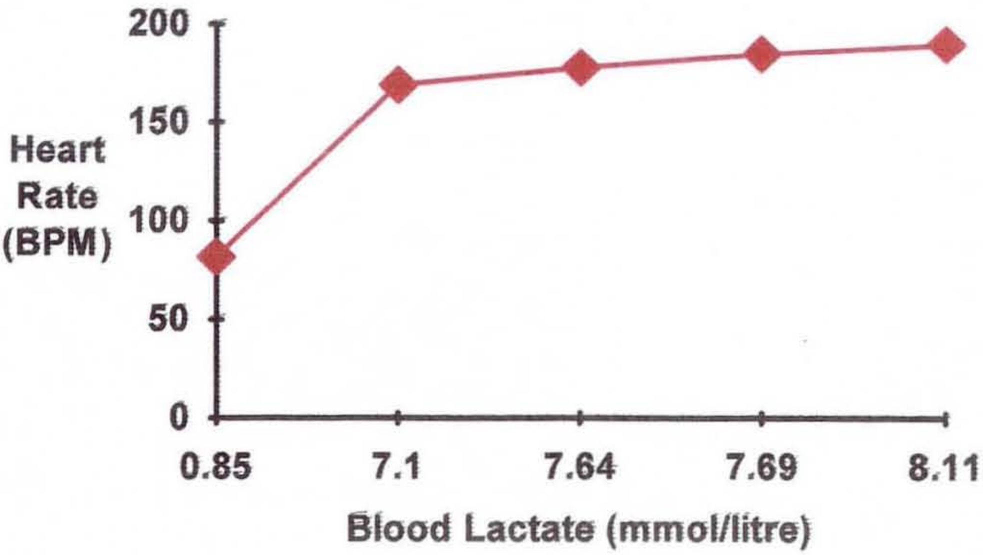
Person		Date	29/03/1997	Duration of exercise: 01:58:28.9
Exercise	1997/03/29 15:30:24	Time	15:30:24	Selected period is: 00:27:00 - 01:57:10
Note	Orrell v Northampton - touch			

APPENDIX N Graphical representation of relationship between subjects' heart rate data and blood lactate results from laboratory calculations of speed lactate threshold

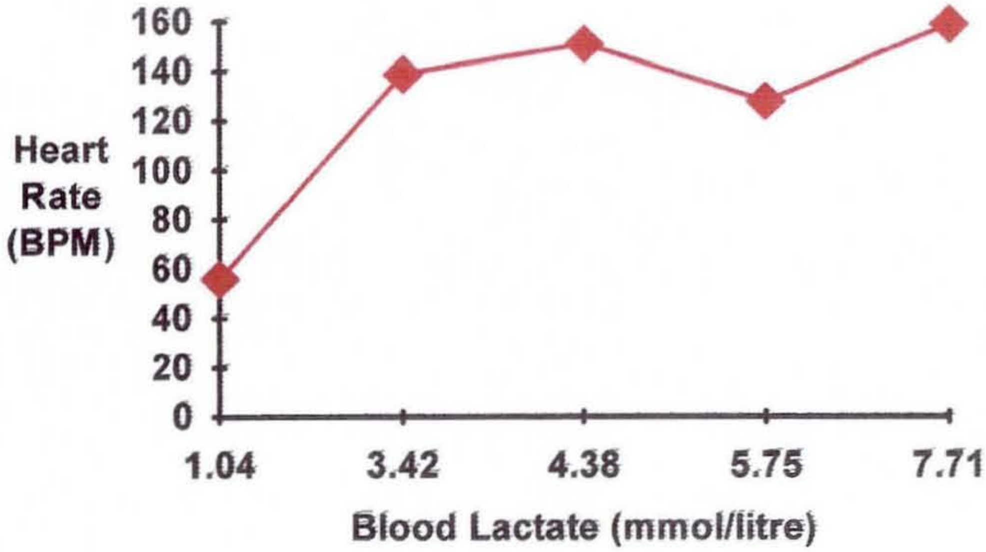
SUBJECT - 1



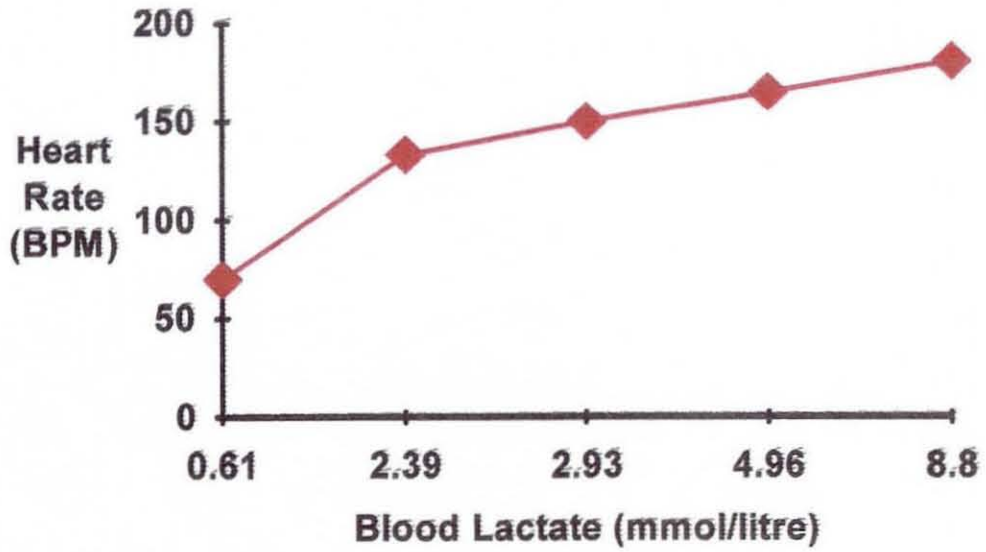
SUBJECT - 2



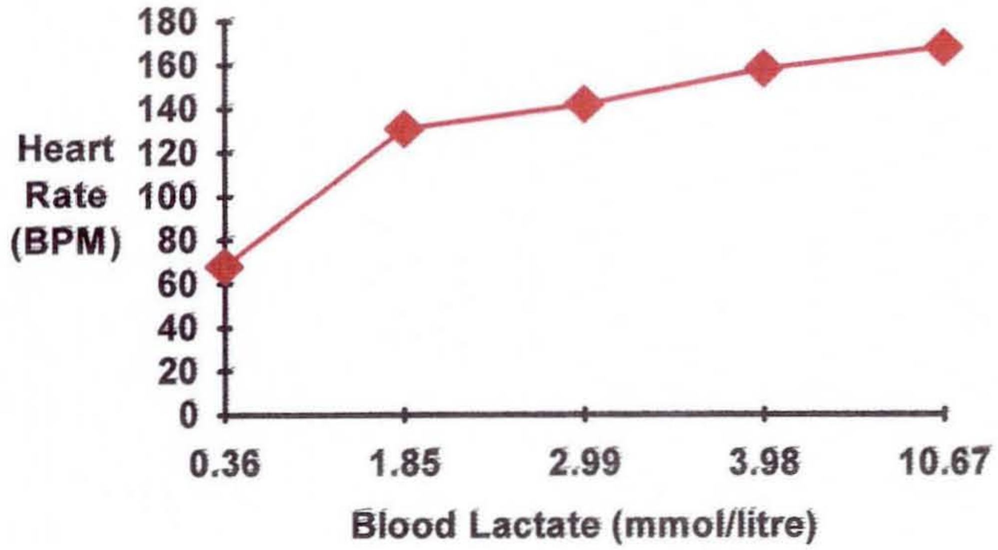
SUBJECT - 3



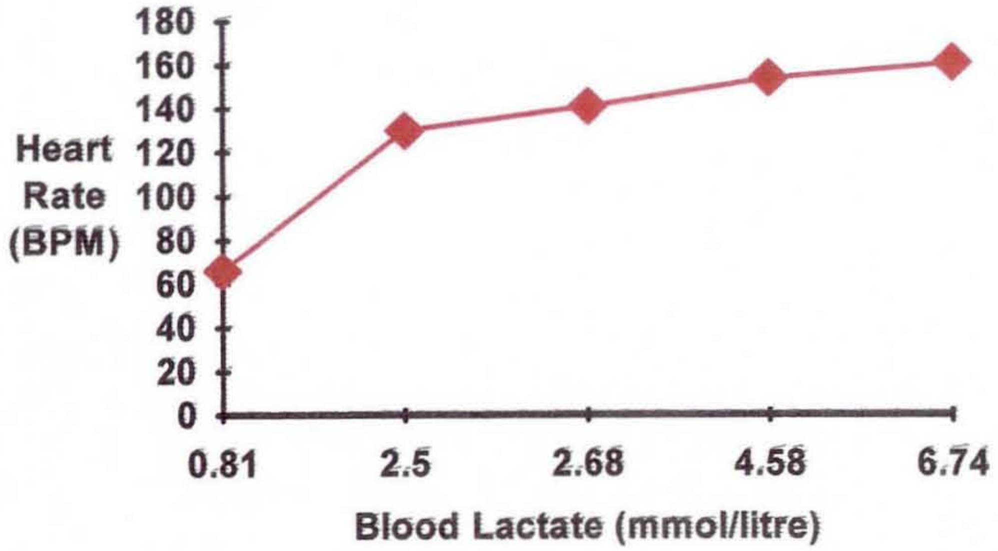
SUBJECT - 4



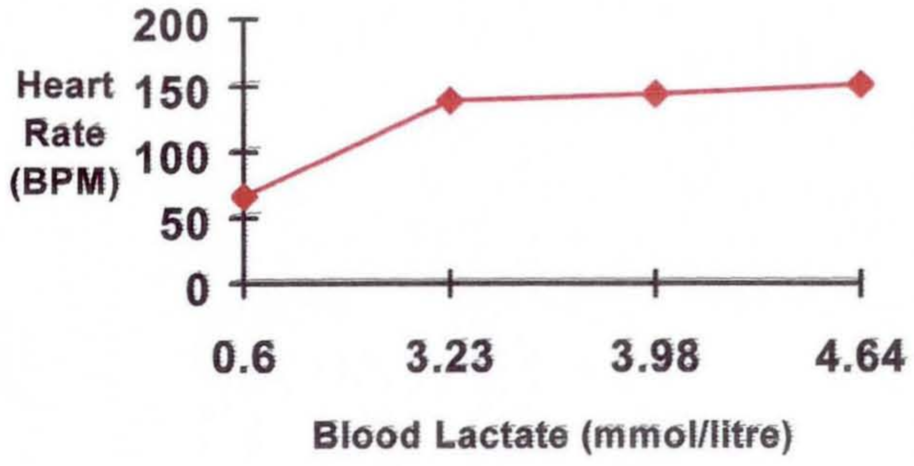
SUBJECT - 5



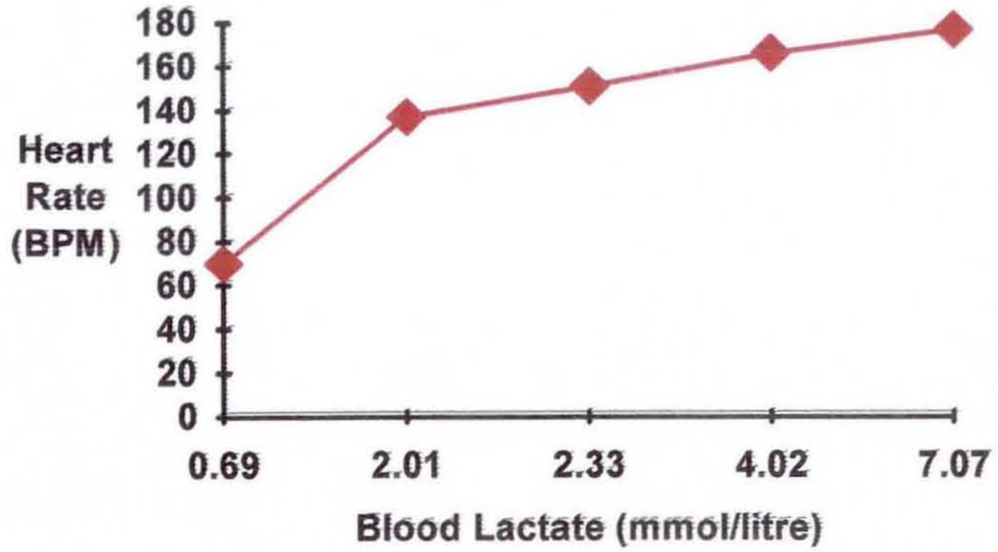
SUBJECT - 6



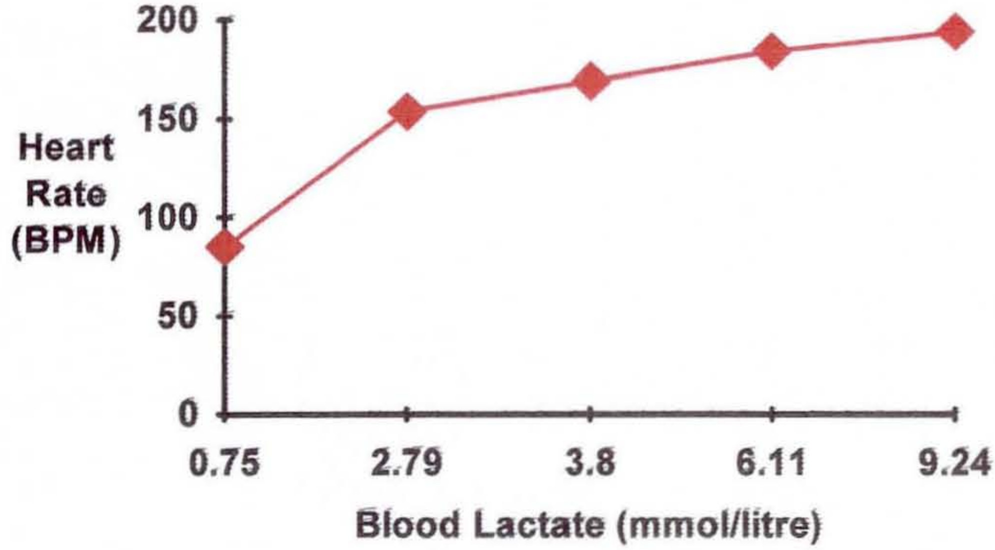
SUBJECT - 7



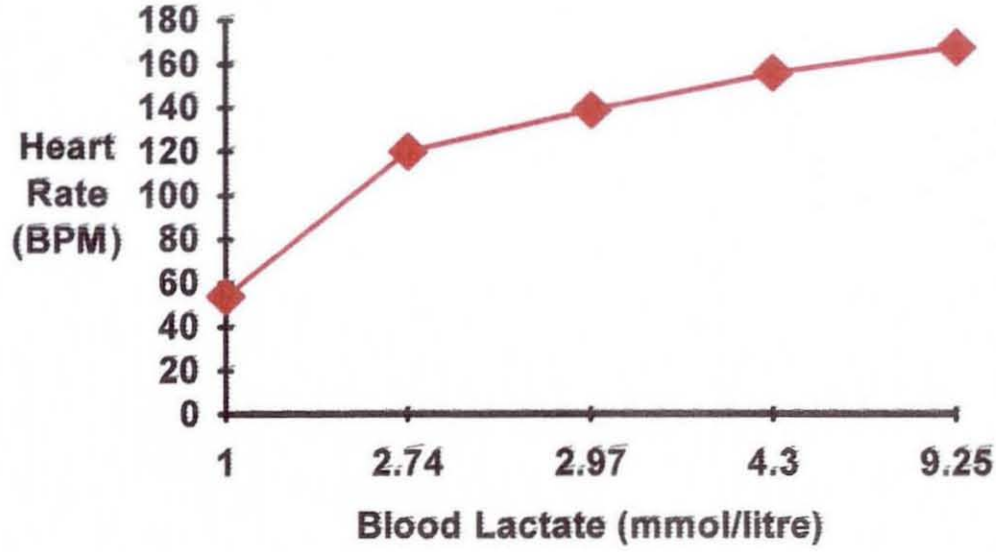
SUBJECT - 8



SUBJECT - 9



SUBJECT - 10



APPENDIX O i) Statistical analysis of results examining correlation between first and second assessments of total distance and time spent in the various movement categories.

Pearson Product correlation test

- - Correlation Coefficients - -

	TOT DIST1	TOT DIST2	TOT TIME1	TOT TIME2
TOT DIST1	1.0000 (8) P= .	.9990 (8) P< .010	------------	------------
TOT DIST2	.9990 (8) P< .010	1.0000 (8) P= .	------------	------------
TOT TIME1	--------	---------	1.0000 (8) P=.	.9990 (8) P<.010
TOT TIME2	---------	----------	.9990 (8) P<.01	1.000 (8) P=.

(Coefficient / (Cases) / 2-tailed Significance)

APPENDIX O — ii) Statistical analysis of results examining first half and second half differences in distance travelled in the referees' subject group.

t-tests for Paired Samples

Variable	Number of pairs	Corr	2-tail Sig	Mean	SD	SE of Mean
FSTHALF				4054.5240	497.480	157.317
	10	.594	.070			
SECHALF				4031.0980	396.177	125.282

Paired Differences Mean	SD	SE of Mean	t-value	df	2-tail Sig
23.4260	412.894	130.568	.18	9	.862
95% CI (-271.940, 318.792)					

APPENDIX O iii) Statistical analysis of results examining differences in total distance travelled between the referees' subject groups in this and Spiller's (1990) study.

t-tests for Independent Samples

Variable	Number of Cases	Mean	SD	SE of Mean
TOTAL				
murgatr	10	8085.6220	799.001	252.666
spiller	6	4878.6500	927.963	378.839

Mean Difference = 3206.9720

Levene's Test for Equality of Variances: F= .530 P= .478

t-test for Equality of Means

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	7.33	14	.000	437.552	(2268.517, 4145.427)
Unequal	7.04	9.40	.000	455.367	(2183.563, 4230.381)

APPENDIX O

iv) Statistical analysis of results examining correlation between total distance covered by referee's subject group and the total points scored in each match.

Pearson Product correlation test

-- Correlation Coefficients --

	TOTAL DIS	TOTAL PTS
TOTAL DIS	1.0000	.2130
	(10)	(10)
	P= .	P> .100
TOTAL PTS	.2130	1.0000
	(10)	(10)
	P>.100	P= .

(Coefficient / (Cases) / 2-tailed Significance)

APPENDIX O v) Statistical analysis of results examining differences in total distance travelled between the referees' subject groups in this and Murray's (1987) study.

t-tests for Independent Samples

Variable	Number of Cases	Mean	SD	SE of Mean
TOTAL				
murgatroyd	10	8085.6220	799.001	252.666
murray	6	8768.8333	597.827	244.062

Mean Difference = -683.2113

Levene's Test for Equality of Variances: F= 1.356 P= .264

t-test for Equality of Means

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	-1.80	14	.093	378.785	(-1495.63, 129.203)
Unequal	-1.94	13.10	.074	351.293	(-1441.54, 75.118)

APPENDIX O vi) Statistical analysis of results examining differences in total distance travelled between the referees' subject groups in this and HealthPac's (1995) study.

t-tests for Independent Samples

Variable	Number of Cases	Mean	SD	SE of Mean
TOTAL				
murgatroyd	10	8085.6220	799.001	252.666
STUDY 4	8	10293.7500	1503.065	531.414

Mean Difference = -2208.1280

Levene's Test for Equality of Variances: F= 2.252 P= .153

t-test for Equality of Means

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	-4.01	16	.001	550.625	(-3375.40, -1040.85)
Unequal	-3.75	10.12	.004	588.422	(-3517.10, -899.151)

APPENDIX O vii) Statistical analysis of results, examining differences in the high intensity (running and sprinting) movement categories, in terms of distance travelled, between the referees' subject groups in this and Spiller's (1990) study.

t-tests for Independent Samples

Variable	Number of Cases	Mean	SD	SE of Mean
RUNSPR				
murgatr	10	1245.8800	309.356	97.827
spiller	6	547.4333	148.965	60.815

Mean Difference = 698.4467

Levene's Test for Equality of Variances: F= 2.444 P= .140

t-test for Equality of Means

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	5.13	14	.000	136.086	(406.572, 990.321)
Unequal	6.06	13.63	.000	115.189	(450.769, 946.125)

APPENDIX O viii) Statistical analysis of results, examining differences in the high intensity (running and sprinting) movement categories, in terms of percentage of total distance covered, between the referees' subject groups in this and Spiller's (1990) study.

t-tests for Independent Samples

Variable	Number of Cases	Mean	SD	SE of Mean
RUNSPR2				
murgatr	10	15.5000	4.055	1.282
spiller	6	11.3667	2.663	1.087

Mean Difference = 4.1333

Levene's Test for Equality of Variances: F= .571 P= .463

t-test for Equality of Means

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	2.21	14	.044	1.869	(.124, 8.143)
Unequal	2.46	13.78	.028	1.681	(.522, 7.745)

APPENDIX O ix) Statistical analysis of results examining first half and second half differences in distance travelled in the touch-judges' subject group.

t-tests for Paired Samples

Variable	Number of pairs	Corr	2-tail Sig	Mean	SD	SE of Mean
TFSTHLF				2531.3770	433.503	137.086
	10	.482	.158			
TSECHLF				2374.7440	338.018	106.891

Paired Differences Mean	SD	SE of Mean	t-value	df	2-tail Sig
156.6330	401.058	126.826	1.24	9	.248
95% CI (-130.266, 443.532)					

APPENDIX O x) Statistical analysis of results examining differences in the total distance covered between the touch-judges' subject groups in this and Murray's (1987) study.

t-tests for Independent Samples

Variable	Number of Cases	Mean	SD	SE of Mean
TOUCH				
murgatr	10	4906.1210	665.968	210.598
murray	2	5683.5000	255.266	180.500

Mean Difference = -777.3790

Levene's Test for Equality of Variances: F= .947 P= .353

t-test for Equality of Means

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	-1.58	10	.146	493.363	(-1876.66, 321.902)
Unequal	-2.80	4.62	.041	277.366	(-1508.18, -46.576)

APPENDIX O xi) Statistical analysis of results examining differences in the total distance covered between the touch-judges' subject group and the referees in Spiller's (1990) study.

t-tests for Independent Samples

Variable	Number of Cases	Mean	SD	SE of Mean
TCHTOTAL				
murgatr	10	4906.1210	665.968	210.598
spiller	6	4878.6500	927.963	378.839

Mean Difference = 27.4710

Levene's Test for Equality of Variances: F= 2.614 P= .128

t-test for Equality of Means

Variances	t-value	df	2-Tail Sig	SE of Diff	95% CI for Diff
Equal	.07	14	.946	397.545	(-825.178, 880.120)
Unequal	.06	8.14	.951	433.440	(-969.141, 1024.083)

APPENDIX O xii) Statistical analysis of results examining correlation between total match distance covered by the referees' subject group and the physiological variables of $\dot{V}O_2$ max and $\dot{V}O_{2OBLA}$

Pearson Product correlation test

-- Correlation Coefficients --

	TOTALDIS	$\dot{V}O_2$ max	$\dot{V}O_{2OBLA}$
TOTALDIS	1.0000	.2630	.1600
	(10)	(10)	(10)
	P= .	P> .10	P>.10
$\dot{V}O_2$ max	. 2630	1.0000	.8200
	(10)	(10)	(10)
	P>.10	P= .	P=.000
$\dot{V}O_{2OBLA}$	.1600	.8200	1.0000
	(10)	(10)	(10)
	P>.10	P=.000	P= .

(Coefficient / (Cases) / 2-tailed Significance)

APPENDIX O xiii) Statistical analysis of results examining correlation between total match distance covered by the touch-judges' subject group and the physiological variables of $\dot{V}O_2$ max and $\dot{V}O_{2OBLA}$

Pearson Product correlation test

-- Correlation Coefficients --

	TOTALDIS	$\dot{V}O_2$ max	$\dot{V}O_{2OBLA}$
TOTALDIS	1.0000	.3660	.4800
	(20)	(20)	(20)
	P= .	P>.100	P>.100
$\dot{V}O_2$ max	.3660	1.0000	.8200
	(20)	(20)	(20)
	P>.100	P= .	P=.000
$\dot{V}O_{2OBLA}$	.4800	.8200	1.0000
	(20)	(20)	(20)
	P>.100	P=.000	P= .

(Coefficient / (Cases) / 2-tailed Significance)

APPENDIX O xiv) Statistical analysis of results examining correlation between multi-stage fitness test and adapted Bangsbo (1994) intermittent field test.

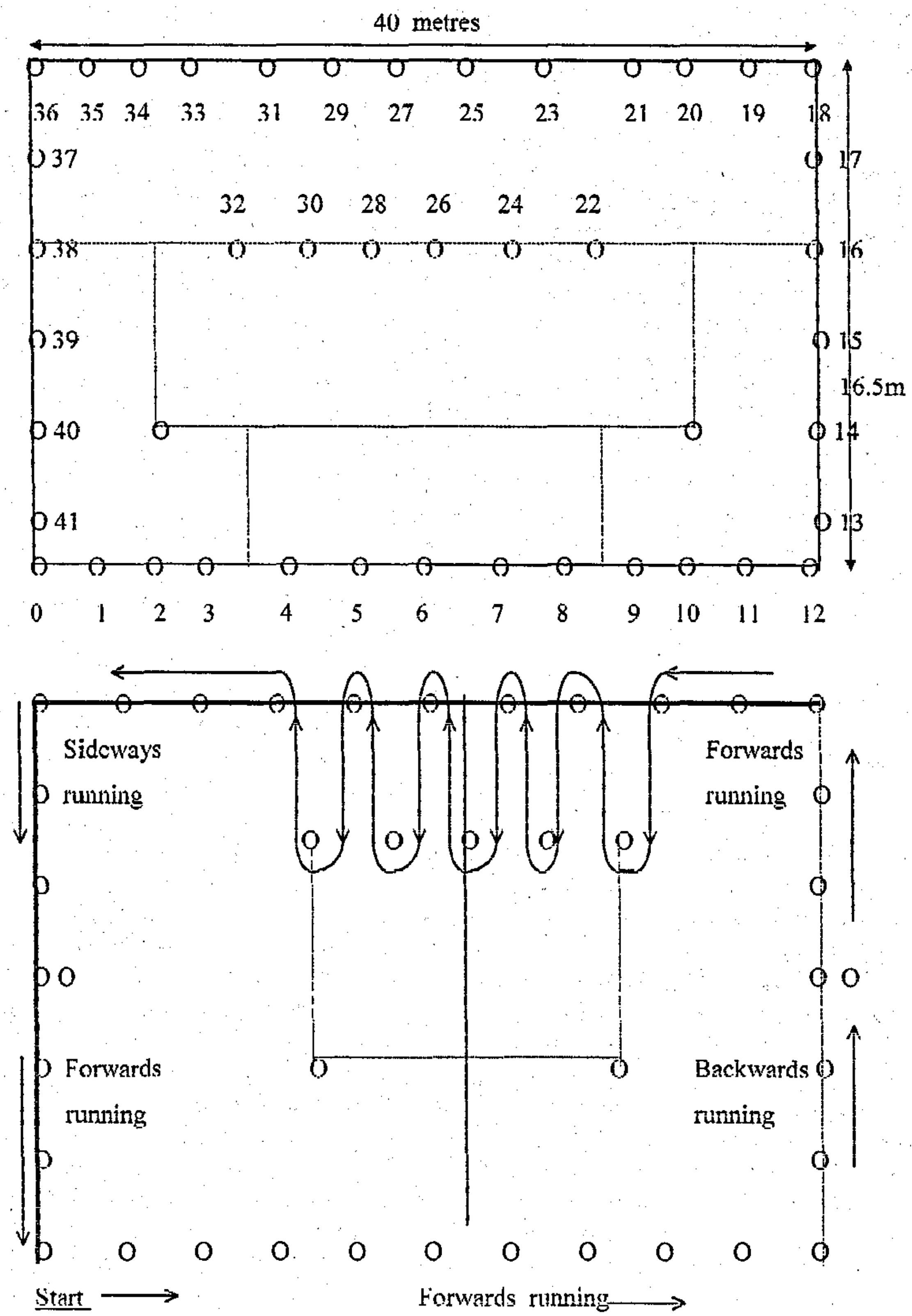
Pearson Product correlation test

-- Correlation Coefficients --

	BANGSBO	MFT
BANGSBO	1.0000	.4208
	(20)	(20)
	P= .	P= .065
MFT	.4208	1.0000
	(20)	(20)
	P= .065	P= .

(Coefficient / (Cases) / 2-tailed Significance)

APPENDIX P Intermittent field test for assessing player's endurance capacity in Association football. (Bangsbo, 1994)



APPENDIX Q Sample of letter to subjects regarding testing dates

Paul Murgatroyd
19 Westkirke Avenue
GRIMSBY
Lincolnshire
DN33 2HS
Tel: 01472 878246

4.2.97.

Following our recent conversation, I have pleasure in confirming your testing date as .... April 1997 at .... Please find enclosed a map of Loughborough University and the car park you are advised to use on your arrival. The laboratory where the tests will be carried out is also marked on the map.

It is expected that the testing will take no more than three hours, allowing for rest periods and other testing of subjects who will be there with you. It will be advisable to bring two t-shirts and plenty of other warm gear for the tests, as there will be a degree of waiting and it is likely that you will go cold during that time. Also please bring plenty of liquid to rehydrate yourself with.

Finally could I thank you in advance for your efforts and point out that the RFU are willing to pay expenses incurred for the trip (agreed with Steve Griffiths), so you should not find yourself out of pocket.

If there are any problems between now and the testing date, please don't hesitate to call me.

Yours sincerely
Paul

APPENDIX R
Sample of medical questionnaire and informed consent read and signed by subjects prior to testing

CONFIDENTIAL

HEALTH HISTORY QUESTIONNAIRE

NAME: DATE:

DATE OF BIRTH:

ADDRESS:

TELEPHONE:

PAST HISTORY (Have you ever had?)

	YES	NO	NOTES
Rheumatic fever / heart murmur			
High blood pressure			
Any heart trouble			
Disease of arteries			
Varicose veins			
Lung disease			
Asthma			
Kidney disease			
Liver disease			
Diabetes			
Epilepsy			
Thyroid disease			
Peptic ulcer			
Any blood clotting disorder			
Any "easy" bleeding, for example, after tooth extraction			
Any abnormal bruising			
Any hypersensitivity to heparin			
Any form of depressive illness			

FAMILY HISTORY (Have any of your immediate family had?)

	YES	NO	NOTES
Heart disease			
High blood pressure			
High cholesterol			
Stroke			
Diabetes			
Heart operations			
Any blood clotting disorders			
Any abnormal bruising			
Other family illnesses?			

PRESENT SYMPTOMS (Have you recently had?)

	YES	NO	NOTES
Chest pain or discomfort			
Shortness of breath			
Heart palpitations			
Skipped heart beats			
Coughing on exertion			
Coughing of blood			
Dizzy spells			
Frequent headaches			
Frequent colds			
Recurrent sore throat			
Back pain			
Aching joints			
Recurrent injury			
Are you presently taking any medications?			
Have you had any surgery in the last 12 months?			
Any other medical problems not already indicated?			
<u>For female subjects only</u>			
Are you pregnant; hoping to become pregnant; or have you had a baby in the last 2 months?			

STATEMENT OF INFORMED CONSENT

Before you can undertake any of the **fitness** testing procedures, it is necessary for you to read and sign the following statement which details the test procedures and any risks, involved.

TEST ONE: MAXIMAL OXYGEN UPTAKE (V02MAX)TEST

The purpose of this test is to determine your level of endurance fitness by establishing your maximum-ability to use oxygen you breathe in, to provide energy for working muscles (known as your V02max). You will be required to cycle 1 run 1 row for as long as possible (usually between 9 and 12 min.) at a constant speed on the equipment. The workload will gradually increase over time. Samples of air will be taken throughout this procedure.

When you feel that you will only he able to maintain the, exercise speed for minute longer, you must raise your forefinger to indicate to the sport scientist that you have 1 minute left. At this point, the sport scientist will immediately proceed to take a final 60 second sample of air after which- the test will stop.

TEST TWO: SPEED - LACTATE

The purpose of this test is to establish you training status (how well trained you are) by measuring the amount-of-lactate that your body produces in response to different exercise intensifies. You will be asked to exercise for 4 minutes at four different submaximal speeds (total = 16 minutes). The speeds at which you exercise during each 4 min stage will be selected according to your exercise ability. In the last 45 seconds of each 4 minute stage, two finger prick blood samples will be taken from the thumb of your right hand. These blood samples will subsequently be analysed to determine blood lactate concentration.

POSSIBLE RISKS/DISCOMFORTS

During the $\dot{V}O_2$ max test you will reach your maximal ability to extract oxygen from the air that you breathe in. This will require maximal effort for a duration of around 1 to 2 minutes. Following this however, subjects usually fully recover within 5 minutes. If at any point in time during the test you experience intolerable discomfort then stop exercising immediately. The sport scientist will be vigilant at all times during his observations of the individual being tested and will be ready to end the test should you report, or even appear, unduly stressed.

The procedures for blood sampling will be carried out in accordance with the Code Of Practice For Workers Having Contact With Body Fluids thereby minimising any risks of infection.

INFORMED CONSENT

I have read and understood the above outline of procedures and requirements which are involved with this testing. I have had the opportunity to ask the sport scientist for further information and for clarification of the demands of each of the procedures. I am aware that I have the right to withdraw from the testing at any time with no obligation to provide reasons for my decision.

I agree to take part in the above two tests

Sign ______________________________ Print ______________________________

Witnessed by (sign) ____________________ Print ______________________________

Date ________________

APPENDIX S
Lactic Acid Assay

Reagents

For the lactic acid assay, hydrazine buffer (pH 9.4), a reaction mixture and lactate diluent (0.07M HCL) will be needed. The hydrazine buffer and the lactate diluent will be already prepared and stored respectively in a labelled volumetric flask and in a brown glass Oxford dispenser. The reaction mixture (RM) must be prepared immediately prior to use. The chemicals used to prepare the RM are kept in the refrigerator in the biochemistry lab.

The RM contains: 2.0mg NAD (weighed on Oertling balance in biochem lab)
10.0 µl LDH (yellow top pipette)
per 1 ml hydrazine buffer (2 of White tip, P5000)

This will make 1 ml of RM. 200µl of hydrazine buffer is required per fluorimeter ('lactate') tube for the assay. To make the required amount for a batch of samples, double the number of samples (each will be analysed in duplicate), add 17 tubes for the blanks and standards, add five tubs to allow for some loss in pipetting and multiply by 200µl.

The number of 17 tubes for the blanks and standards comprises:-

Blank – 4 tubes.
Top standard (e.g. 20mmo1.1^{-1}) – 4 tubes.
Three in between standards – in triplicate (i.e. three tubes each gives 9).
The extra blank and top standard tube are used to set the range on the photometer. Once the tube has been read in the photometer the fluorescence changes, and so it should not be used again.

e.g. For 15 blood samples
30 + 17 + 5 = 52 tubes
52 x 200µl = 10400 µl or 10.4 ml of RM

For this batch of samples 10.4 ml of RM is required, so the amounts listed above are multiplied by 10.4 (20.8mg NAD, 104 µl LDH, 10.4 ml hydrazine buffer).

Standards

These are made from 1.0 M Sodium L-Lactate stock solution, and represent concentrations of 0.5, 1.0, 2.5, 5.0, 10.0, 15.0, 20.0 $mmo1.1^{-1}$. These stock standards will be made up into working standards. Select the blank (just perchloric acid) and four standards in the appropriate range, for example high intensity work should include 20 $mmo1.1^{-1}$. The standards should be run on their won, as a practice, several times (using the same procedure as outlined below). When the 'r' of the regression equation produced on the laboratory "ASSANAL" programme for the standards is $\geq$0.99, then analysis of samples can be undertaken.

Procedure

1) Remove samples and standards from the freezer and allow to thaw at room temperature for at least one hour.

2) Mix samples thoroughly using the Whirlmix, and centrifuge for 3 minutes.

3) Pipette 20µl of either standard or supernatant (yellow top, yellow tip) into a glass fluorimeter ("lactate") tube and add 200µl of RM (yellow top, tip). Arrange the tubes in order in white test tube racks for ease of identification.

4) Mix tubes thoroughly (Whirlmix) and allow to incubate for 30 minutes. Covering the tube tops with a sheet of paper will prevent contamination (do not use tissue as this will affect fluorescence of the tubes).

5) Add 1.0ml of lactate diluent to each tube to stop the reaction and mix thoroughly (Whirlmix).

6) Read fluorescence of the samples, blanks and standards on the Perkin Elmer fluorimeter.

7) Lactic acid concentrations can then be calculated on a BBC computer using the "ASSANAL" programme.