FIT TO REF

LEVEL III REFEREE PROJECT 2004

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AIM

The aim of this project was to examine the fitness requirements for a 1st/2nd grade referee in the Brisbane Rugby Union Competition. This was to be determined by measurements of distance traveled whilst refereeing, approximations of stand, walk, jog, run and sprint times, half and full time lactate and Creatine Kinase levels, perceived exertion scale and heart rate measurements.

These results are then to be compared to corresponding measurements during and after the completion of the two current fitness tests, the Beep or Multistage test, and the 2.4 km run.

This information is then to be used to determine the relevance and effectiveness of our current fitness testing systems.

HYPOTHESES

It is hypothesised that the results will show that the current fitness tests are one dimensional and that a more specific fitness testing program, at least at the higher level of the sport, would be more accurate and in keeping with the current fitness programs undertaken by many referees.

WHAT IS FITNESS?

Fitness is the ability of the body systems to cope with the demands placed upon them. The more efficiently the body copes, the fitter the person is said to be.

HOW TO IMPROVE FITNESS

Fitness is improved by gradually increasing the demands placed on the body systems by means of a specific exercise programme (or training schedule). The body systems will then adapt and fitness will increase. The more stress the body is subjected to, the more it will adapt, and the fitter, the stronger, and faster the person will become.

FITNESS AND TRAINING - THE PRINCIPLES OF TRAINING

There are 4 principles of training: -

1] THE PRINCIPLE OF OVERLOAD - To become more efficient, the body systems has to be overloaded - or worked harder than normal. Overload can be achieved by: -

Increasing intensity e.g. heavier weights or faster running.

Increasing frequency, i.e. train more often but not more intensely.

Increasing duration, i.e. each training session is made longer.

Overload training must not be done daily. This type of training damages muscle fibre and so time must be allowed for the damage to heal. However, it has been shown that light training assists tissue healing.

2] THE PRINCIPLE OF PROGRESSION - The body cannot become fit overnight. It can only become progressively fitter. Training must also be progressive, i.e. the first few sessions should be fairly easy and then progressively become harder. In the early stages the body adapts quite quickly so that even with light training, fitness will improve quite quickly. But as the body gets fitter it becomes harder and harder to improve, and the only way is to make the training harder and harder

3] THE PRINCIPLE OF SPECIFICITY - Training will only improve those parts of the body being trained. Cross-Country running will improve cardio-vascular fitness, but will do nothing for arm strength. In other words training is specific to the parts being trained. When training for a specific event, an athlete must work specifically on the type of fitness required for that event.

4] THE PRINCIPLE OF REVERSIBILITY - Just as the body adapts to more stress by becoming fitter, so also does it adapt to less stress by becoming unfit, i.e. it becomes less efficient at coping with the demands of exercise. This reversibility of fitness happens quickly. It only takes 3-4 weeks for a trained athlete to become unfit. The quickest reverse takes place in aerobic fitness. Muscles quickly lose their ability to use oxygen efficiently. Strength losses occur much more slowly so anaerobic activities are not so badly affected by breaks in training. The wasting away of muscle tissue is called atrophy.

WHAT IS MEANT BY 'FITNESS?'

SPEED

STRENGTH

ENDURANCE - AEROBIC

- ANAEROBIC

FLEXIBILITY

WHAT IS SPEED?

Speed is the quickness of movement of a limb, whether this is the legs of a runner or the arm of the shot putter. Speed is an integral part of every sport and can be expressed as any one of, or combination of, the following:

- Maximum speed
- Elastic strength (power)
- Speed endurance

WHAT IS SPEED INFLUENCED BY?

Speed is influenced by the athlete's mobility, special strength, strength endurance and technique.

ENERGY SYSTEM FOR SPEED

Energy for absolute speed is supplied by the anaerobic alactic pathway. The anaerobic (without oxygen) alactic (without lactate) energy system is best challenged as an athlete approaches top speed between 30 and 60m while running at 95% to 100% of maximum. This speed component of anaerobic metabolism lasts for approximately six seconds and should be trained when no muscle fatigue is present (usually after 24 to 36 hours of rest)

WHAT IS STRENGTH?

The common definition is *the ability to exert a force against a resistance*. The strength needed for a sprinter to explode from the blocks is different to the strength needed by a weight lifter. This therefore implies that there are different types of strength.

WHAT ARE THE CLASSIFICATIONS OF STRENGTH?

The classifications of strength are:

- Maximum strength -*the greatest force that is possible in a single maximum contraction*
- Elastic strength - *the ability to overcome a resistance with a fast contraction*
- Strength endurance - *the ability to express force many times over*

HOW DO WE GET STRONG?

A muscle will only strengthen when it is worked beyond its normal operation, ie overloaded. Overload can be progressed by increasing the:

- Number of repetitions of an exercise
- Number of sets of the exercise
- Intensity - reduced recover time

HOW DO WE DEVELOP STRENGTH?

- Maximum strength can be developed with:
- Weight training
- Elastic strength can be developed with:
- Conditioning exercises
- Complex training sessions
- Medicine ball exercises
- Polymeric exercises
- Weight training
- Strength endurance can be developed with:
- Circuit training
- Dumbbell exercises
  - Weight training
  - Hill and harness running

WHAT ARE THE EFFECTS OF STRENGTH TRAINING?

Changes that occur within the muscle as a result of strength training are classified as:

- Myogenic - changes within the muscle structure
- Neuogenic - changes to the connection between muscle and nerve

MYOGENIC CHANGES

Strength training results in muscle hypertrophy, and increases the cross-sectional size of existing fibres. This is achieved by increasing:

- Number of myofibrils
- Sarcoplasmic volume
- Protein
- Supporting connective tissue (ligaments and tendons)

Strength training programs increase the intramuscular stores such as adenosine triphosphate (ATP), creatinine phosphate (CP) and glycogen. In women, the potential for hypertrophy is not as great as men due mainly to the lower levels of testosterone in women.

CAPILLARISATION AND INCREASE IN MITOCHONDRIA

Strength training programs cause biomechanical changes that occur within muscle and serve to increase the oxidative capacity of the muscle. The affects of strength training are:

- An increase in ATP, CP and glycogen concentration
- A decrease in oxidative enzyme activity
- A decrease in mitocarbohydratendrial density

These changes vary slightly according to the training intensity.

NEUROGENIC CHANGES

By repeatedly stimulating muscle, you increase the rate of response of the central nervous system. The recruitment patterns become more refined and as a result, gross movement patterns become more efficient and effective.

AEROBIC FITNESS. ITS' MEANING AND SIGNIFICANCE

"Aerobic fitness" refers to endurance, or the ability to sustain work for prolonged periods. This is usually experienced in the abilities to walk, run, climb uphill, swim, etc. Most forms of sports, work, and recreational activities include elements of aerobic fitness. Generally speaking, any activity which lasts less than 12 minutes is not fully aerobic. The term "aerobic" implies that the oxygen necessary to accomplish the work is taken up by the individual during the activity. Strenuous exercise lasting less than 12 minutes includes substantial portions of anaerobic metabolism whereby one uses energy sources stored in the body to perform the work. Since the body's energy sources are limited, anaerobic work cannot last long. Fast runs, lasting 10 to 15 seconds, are mostly accomplished by anaerobic metabolism. With longer exercise

time, more aerobic metabolism is involved, and exercise lasting more than 12 minutes is mostly accomplished by aerobic metabolism. Work is performed by the muscles which use oxygen for the combustion of fat and carbohydrates creating the energy necessary to move the body, or to move objects outside the body.
In aerobic work, oxygen is obtained from the air and is transferred from the lungs to the blood and then to the muscles via the circulatory system. Maximal oxygen uptake, or maximal aerobic power (Vo_2 max) is the indicator of aerobic fitness. Vo_2 max is determined by the measurement of oxygen uptake during the performance of maximal work, typically while running on a treadmill or while cycling. This is done by exercising for at least 12-minutes at sub maximal loads, after which the maximal effort is performed for one or two minutes. Oxygen uptake during this time is measured, giving the value of Vo_2 max. As Vo_2 max increases, the level of aerobic fitness also increases.
Aerobic fitness is dependent upon age and sex and it can be improved by training. It is highest at ages 18, 19 years in males and 15 to 20 years in females, and it decreases with age in adulthood. In general, males have higher Vo_2 max than females. The main reason for this is that aerobic fitness is directly related to fat-free body weight, which consists mainly of the weight of muscles in the body, and on the average, males have a higher muscle mass than females. As with other physiological functions, there are large individual differences in Vo_2 max of people of the same sex and age. Some people show high Vo_2 max without exercising because of genetic and other factors, while other people who exercise regularly do not show high Vo_2 max .

METHODS FOR MEASURING AEROBIC FITNESS

Direct measurement of Vo_2 max is determined by having the subject perform exercise at increased loads, for 12 to 15 minutes. A stationary bicycle or a treadmill are typically used. The test starts with a moderate work load which is maintained for a few minutes. The load is increased gradually every few minutes until reaching the maximum level that the subject can tolerate. This is done by increasing the cycling resistance or the speed and grade of the treadmill. The oxygen uptake measured at the maximal load is the subject's Vo_2 max . The higher the Vo_2 max, the more work one can perform; thus, the better the level of aerobic fitness. These laboratory methods to determine aerobic fitness require maximal work, are expensive, and are beyond the reach and capability of most people.
An alternative method for determining aerobic fitness involves the measurement of heart rate. The ability to perform aerobic work depends upon the delivery of oxygen to the muscles. Oxygen is delivered by the circulatory system and each heart beat indicates a quantity of blood pumped by the heart. Heart rate (HR) is, therefore, a good measure of the severity of exercise. Young people can increase their HR to high levels and deliver large amounts of oxygen to the muscles which is a major reason why their aerobic fitness is better than that of older people.
Training results in an increase in the efficiency of oxygen transport within the body. By lowering the resting HR, and heart rates at sub maximal loads, the heart pumps more blood with every heart beat. This, and other physiological changes, increase the oxygen transport capability. When an individual is tested before and after training while performing exercise at the same load, a lower HR is shown after training because more blood (thus, oxygen) is delivered in each heart beat. Such HR differences during exercise can be used to predict aerobic fitness.
The available methods to predict Vo_2 max consist of HR measurements during the performance of sub-maximal exercise. Since a fit person shows a lower HR than an unfit one when exercising at the same load (same oxygen uptake) and the maximal HR for each age group is known, it becomes possible to extrapolate the oxygen uptake-HR curve to the maximal HR where it represents Vo_2 max.
Age and sex differences in HR have to be considered. At least 3-5 minutes of exercise has to be performed because it takes several minutes for the HR to level off

to the point where it represents the correct level of effort. In most methods of this type, at least three 3 to 5-minutes of testing at each load has to be performed. This type of testing is best done with a treadmill or cycle which automates the test to eliminate the possibility of human error in reading and recording the heart rate and calculating the results.

ABSOLUTE AND RELATIVE Vo_2 MAX

Aerobic fitness is expressed in two ways: Absolute Vo_2 max, and relative Vo_2 max. Absolute Vo_2 max is simply the amount of oxygen that the body uses during the performance of maximal effort; it is expressed in liters of oxygen per minute (liters/min). Relative Vo_2 max is the absolute Vo_2 max divided by body weight in kilograms and it is expressed in milliliters of oxygen per body weight per minute (ml/kg/min).

In general, absolute Vo_2 max is important in activities in which body weight is not lifted such as in swimming, cycling, and the lifting of weights and other objects. Vo_2 max is mainly a function of work capability of the large muscle groups of the legs. Many good swimmers do not show high Vo_2 max because of the specialized upper body work involved in this activity. Relative Vo_2 max is important in such activities as walking, running, climbing uphill in which body weight is lifted.

WHAT IS ANAEROBIC FITNESS?

It is the ability to:-

- Re-charge Creatine phosphate quickly and efficiently,
- Dispose of lactic acid in the muscles and blood.
- Tolerate high levels of lactic acid in the muscles and blood.

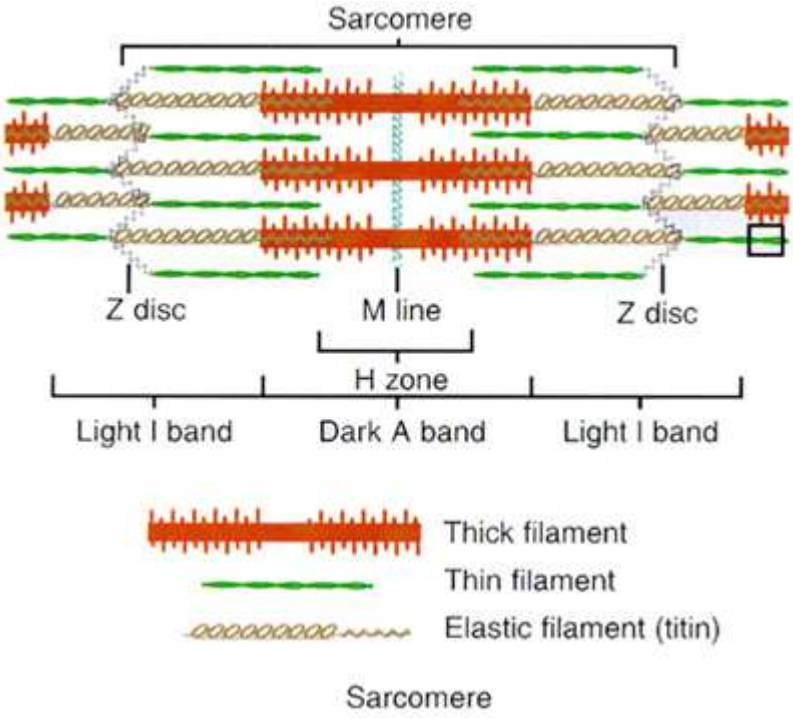
HOW DO WE IMPROVE ANAEROBIC FITNESS?

To improve (1), work flat-out for 15 secs and rest for 4-5mins.
To improve (2), work flat-out for 1 min and rest for 4-5mins
To improve (3), work flat-out for as long as possible and rest for 1-2mins.
To improve anaerobic fitness, the training programme must include all 3 factors.

FLEXIBILITY

Flexibility has for many years been a misunderstood area of health and fitness. Misunderstood in that most athletes knowledge of what flexibility is was poor, and from the point that flexibility was not given the credit it was due.

At the highest level, the (whole) muscle is composed of many strands of tissue called *fascicles*. Each fascicle is composed of *fasciculi* which are bundles of *muscle fibers*. The muscle fibers are in turn composed of tens of thousands of thread-like *myofybrils*, which can contract, relax, and elongate (lengthen). The myofybrils are (in turn) composed of up to millions of bands laid end-to-end called *sarcomeres*.



Each sarcomere is made of overlapping thick and thin filaments called *myofilaments*. The thick and thin myofilaments are made up of *contractile proteins*, primarily actin and myosin.

The energy which produces the calcium flow in the muscle fibers comes from *mitochondria*, the part of the muscle cell that converts glucose (blood sugar) into energy. Different types of muscle fibers have different amounts of mitochondria. The more mitochondria in a muscle fiber, the more energy it is able to produce. Muscle fibers are categorized into *slow-twitch fibers* and *fast-twitch fibers*. Slow-twitch fibers (also called *Type 1 muscle fibers*) are slow to contract, but they are also very slow to fatigue. Fast-twitch fibers are very quick to contract and come in two varieties: *Type 2A muscle fibers* which fatigue at an intermediate rate, and *Type 2B muscle fibers* which fatigue very quickly. The main reason the slow-twitch fibers are slow to fatigue is that they contain more mitochondria than fast-twitch fibers and hence are able to produce more energy. Slow-twitch fibers are also smaller in diameter than fast-twitch fibers and have increased capillary blood flow around them. Because they have a smaller diameter and an increased blood flow, the slow-twitch fibers are able to deliver more oxygen and remove more waste products from the muscle fibers (which decreases their "fatigability").

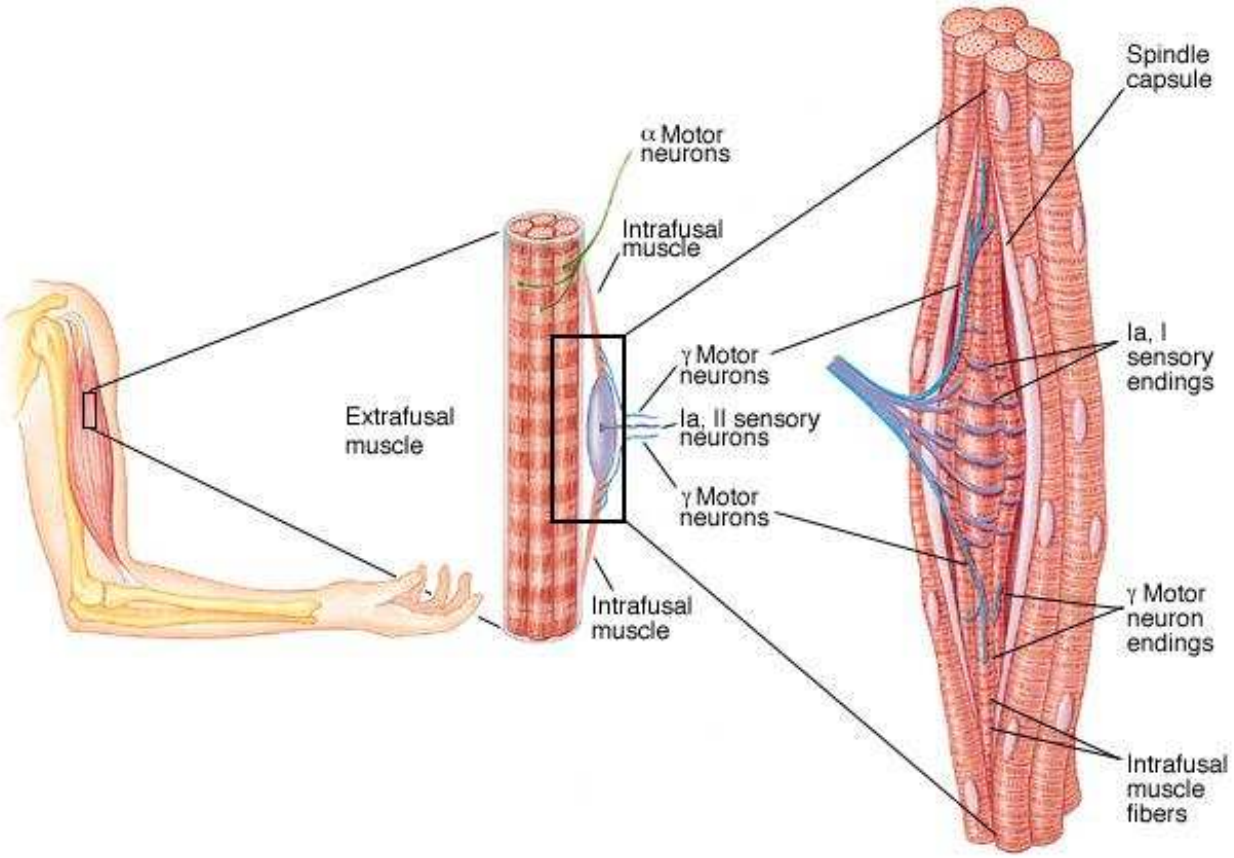
These three muscle fiber types (Types 1, 2A, and 2B) are contained in all muscles in varying amounts. Muscles that need to be contracted much of the time (like the heart) have a greater number of Type 1 (slow) fibers. When a muscle first starts to contract, it is primarily Type 1 fibers that are initially activated, then Type 2A and Type 2B fibers are activated (if needed) in that order. The fact that muscle fibers are *recruited* in this sequence is what provides the ability to execute brain commands with such fine-tuned tuned muscle responses. It also makes the Type 2B fibers difficult to train because they are not activated until most of the Type 1 and Type 2A fibers have been recruited.

The stretching of a muscle fiber begins with the sarcomere, the basic unit of contraction in the muscle fiber. As the sarcomere contracts, the area of overlap

between the thick and thin myofilaments increases. As it stretches, this area of overlap decreases, allowing the muscle fiber to elongate. Once the muscle fiber is at its maximum resting length (all the sarcomeres are fully stretched), additional stretching places force on the surrounding connective tissue. As the tension increases, the collagen fibers in the connective tissue align themselves along the same line of force as the tension. Hence when you stretch, the muscle fiber is pulled out to its full length sarcomere by sarcomere, and then the connective tissue takes up the remaining slack. When this occurs, it helps to realign any disorganized fibers in the direction of the tension. This realignment is what helps to rehabilitate scarred tissue back to health.

When a muscle is stretched, some of its fibers lengthen, but other fibers may remain at rest. The current length of the entire muscle depends upon the number of stretched fibers (similar to the way that the total strength of a contracting muscle depends on the number of recruited fibers contracting). The more fibers that are stretched, the greater the length developed by the stretched muscle.

When the muscle is stretched, so is the muscle spindle.



The muscle spindle records the change in length (and how fast) and sends signals to the spine which convey this information. This triggers the *stretch reflex* (also called the *myotatic reflex*) which attempts to resist the change in muscle length by causing the stretched muscle to contract. The more sudden the change in muscle length, the stronger the muscle contractions will be (plyometric, or "jump", training is based on this fact). This basic function of the muscle spindle helps to maintain muscle tone and to protect the body from injury.

One of the reasons for holding a stretch for a prolonged period of time is that as you hold the muscle in a stretched position, the muscle spindle habituates (becomes accustomed to the new length) and reduces its signaling. Gradually, you can train your stretch receptors to allow greater lengthening of the muscles.

Some sources suggest that with extensive training, the stretch reflex of certain muscles can be controlled so that there is little or no reflex contraction in response to

a sudden stretch. While this type of control provides the opportunity for the greatest gains in flexibility, it also provides the greatest risk of injury if used improperly.

CURRENT FITNESS TESTING

BEEP TEST

The beep or multistage fitness test is a very common test of aerobic fitness.

- **Description:** This test involves continuous running between two lines 20m apart in time to recorded beeps. The time between recorded beeps decrease each minute (level). There are several versions of the test, but one commonly used version has an initial running velocity of 8.5 km/hr, which increases by 0.5 km/hr each minute.
- **Scoring:** The athletes score is the level and number of shuttles reached before they were unable to keep up with the tape recording. This score can be converted to a VO2max equivalent

- **Equipment required:** Flat, non-slip surface, marking cones, 20m measuring tape, pre-recorded audio tape, tape recorder, recording sheets.
- **Target population:** Suitable for sports teams and school groups, but not for populations in which a maximal exercise test would be contraindicated.
- **Validity:** There are published VO_{2max} score equivalents for each level reached. The correlation to actual VO_{2max} scores is high.
- **Reliability:** Reliability would depend on how strictly the test is run, and the practice allowed for the subjects.
- **Advantages:** Large groups can perform this test all at once for minimal costs. Also, the test continues to maximum effort unlike many other tests of endurance capacity.
- **Disadvantages:** Practice and motivation levels can influence the score attained, and the scoring can be subjective. As the test is usually conducted outside, the environmental conditions can be often affect the results.
- **Variations:** You will find that there are several different variations of this test, and you should ensure that you have norms relevant to the correct test.

Currently the ARU AND IRB requires their contracted referees to reach level 12.5 of the beep test. This score reflects a VO_{2max} of 55.45.

2.4 km RUN

The second test of commonly used by both the ARU and the IRB is the 2.4 km run. The most common place to carry out the test is on an athletics track or football field. Minimal research has been done of the 2.4 km run as a measure of fitness although it is a test commonly used by both military and law enforcement agencies around the world to measure fitness. In comparison to the beep test the 2.4 km run varies in that:

- It is basically a straight line running test with no need for turning, acceleration, deceleration or agility
- The intensity of the exercise is mostly constant apart from mild changes in speed particularly at the start and end of the run

- The standard for the 2.4 km run set by the ARU and IRB is 9:15 and therefore less than 12 minutes. As previously discussed exercise which is less than 12 minutes is generally considered to not be completely aerobic

RESULTS

Results of the fitness testing undertaken were as follows:

	Lactate ½ time mmol/L	Lactate Full time mmol/L	CK+ ½ time U/L	CK+ Full time U/L	Distance traveled (metres)	Perceived exertion	Max Heart rate (BPM)
2.4 km run	N/A	15.3	N/A	408	2400	10	185
Beep test	N/A	17.1	N/A	446	2480	9	183
Game 1	3.6	3.1	261	285	6985	7	163
Game 2	5.2	2.3	336	365	7025	8	174
Game 3	9.1	16.2	258	429	7945	8	180
Game 4	4.9	4.5	327	348	7110	7	165
Game 5	12	14.7	316	418	7235	8	181

EXPLANATION OF RESULTS

The 2.4 km run was run in a time of 9 minutes and 12 seconds. An attempt was made to run the distance in a time as close to the ARU and IRB required time of 9 minutes and 15 seconds. Assuming that 9:15 is a time representative of the VO_{2max} and fitness level required to referee at this level, this should best resemble the relative physical effort required to referee a game.

The Beep test was performed up to the level of 12.5 so as to best resemble the relative physical effort required to referee a game.

Heart rate levels were recorded at ¼, ½, ¾ and full time and max rate also recorded.

The standards of game varied. They included two second grade games, one first grade game, one colts 1st grade game and a representative U19 game.

Distances run during the games were measured by estimation from the video's of the games. Therefore trying to measure estimations of stand, walk, jog, run and sprint would have been inaccurate. Standard pedometers could not be used because they only measure the number of steps taken assuming that all steps are of even length. GPS pedometers can be purchased. The accuracy of these is currently unclear and the cost is significant. However, if greater accuracy were desirable this would most likely be a preferred option.

The 2.4 km run, beep test and games were all performed between the times of 1:30pm and 5:00pm. Temperatures varied between 22 degrees and 25 degrees.

DISCUSSION OF RESULTS

Lactate analysis has been used by many athletes and physiologists over the last decade as a tool for predicting endurance performance. Specifically, the higher the percentage of VO2max, or the higher the pace at which the lactate threshold occurs, the fitter the athlete. Many researchers have placed the lactate threshold - the maximum concentration that an athlete can maintain during a steady state effort - at around 4mmol/L. But others have found that lactate concentrations can vary widely, with some athletes capable of maintaining concentrations as high as 8mmol/L over sustained periods.

A new study has measured the lactate response to a cycling time trial in which the participants were instructed to cycle as far as they could in a period of one hour, with lactate samples collected every 10 minutes. The athletes averaged 40.8k during the trial at an average 83% of maximum heart rate. Lactate concentrations ranged between 5 and 12mmol/L, with an overall average of 7.6mmol/L. Mean lactate concentrations and pace remained relatively stable throughout, suggesting the athletes were maintaining a constant maximum steady state effort.
The implication is that when athletes select their own pace, a constant effort can be maintained despite high lactate concentrations. This raises serious doubts not just over whether 4mmol/L can be regarded as the lactate threshold point but whether the concept of a lactate threshold is relevant to athletic performance. It may be that the long-term accumulation of lactate during a race or time trial is much higher than the levels found during incremental tests in the laboratory, which questions the validity of lab-based lactate testing as a way of predicting performance.

The study found a wide degree of variation in lactate concentrations between athletes. Since there was no correlation between lactate concentration and performance, this suggests a link with individual muscle fibre type. For example, an athlete with a greater proportion of type IIa fibres will produce more lactate than one with more type I fibres, even with identical performances.
So is there any point in lactate testing? Certainly the observed variations in concentrations that can be maintained for long periods would cast doubt on its use for predicting performance. And there may be little association between lactate found in the lab and that found in competition conditions.

From the results recorded during lactate testing it is clear that depite measurements only being taken at half time and at full time that lactate levels can vary significantly during a game. In particular the two games from which high lactate levels were measured were quick games which had particularly fast paced endings.

The results seem to agree with the research discussed above that lactate levels may not be as important a measure of fitness as previously thought. From results taken at half and full times, 7 of the 10 were higher than 4 mmol/L. Taking into account that two of the results can be explained by a particularly fast finish to the match 5 of the remaining 8 results were above the level of 4 mmol/L and only one was under 3 mmol/L.

What can be concluded is that testing which requires a changing level of intensity would be more specific at imitating lactate and therefore muscle fibre I type performance and anaerobic requirements than a constant pace or effort test.

Litle research has been done on the levels of Creatine Kinase in the bodies of athletes during and post exercise. What is know in is that when CK+ remains in the body for an extended period at high levels post exercise that it is a sign that a very high level of exercise has been performed. The one notable result which can be seen from the results is that no full time levels of CK+ were lower than half time levels. Therefore, at some stage of each game, most likely in the first half, a maximum or close to maximum effort was required for a period of time. The implications we can take from this is that at some stage of testing, preferably well before the end of testing, maximal effort should be required to increase the levels of CK+ in the body and therefore replicate required game performance.

The relevance of differnces in distance is hard to determine. A fitness test over a period of 35 to fourty minutes, over a distance of 7 – 8 km with varying intensity is probably very difficult to develop and simply inpractiable in terms of implementation.

Percieved exertion levels are expected as these were fitness tests and should therefore require a greater effort. The fact that 10 was not recorded for the beep test is also expected as the level finished was below the performance recorded two months later of 12.10.

From research undertaken into VO_{2max} it is clear that a test which starts slowly and builds in intensity is the best measure. The test must also continue over a period of greater than 12 minutes so that it is a truly aerobic test.

CONCLUSIONS

The following conclusions are based upon the results discussion:

- The Beep test is as effective measure of VO_{2max} and therefore aerobic fitness that we have available to us. This is assuming that level 12 is reached by the participant so as the test is truly aerobic. Heart rate levels could also be recorded so as to gain greater accuracy of VO_{2max}
- The development of a test which varies in intensity and includes maximal and close to maximum efforts throughout the test would be beneficial to replicate game performance requirements
- Other areas of fitness that contribute to aerobic fitness, anaerobic fitness and speed levels should also be tested so as to identify specific weaknesses and strengths of the athlete. These might include for example specific strength, power and flexibility tests
- So where to from here? As rugby tactics change and the need for better performance by referees has increased so has the need to not only understand the game but also to always be in the best possible position. Obviously fitness is a key component of this. The next step in research as I see it is to fragment the running distances, times, speeds and rest times of the referee. This would of course require a significantly higher level of technology than was available for this project but would give us a much clearer picture of not only what requirements we have on the field physically. But would also allow us to train a with far more relevance to achieving the desired outcome on the field. A testing system which mimicks the on field demand of referees, particularly in relation to the changing of speed and variation in exertion whilst still effectively measuring $VO_{2max,}$ and testing an individuals lactate and Creatine Kinase

levels could then be developed with greater confidence of relevance and specificity

REFERENCES

FH Martini, Fundamentals of Anatomy and Physiology, 1998, Prentice Hall

ET Howley, Exercise Physiology with Power Web Health and Human Performance, 2001, Mosby

AC Silverthorne, Human Physiology: An Integrated Approach, 2001, Benjamin Commings