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Title

An Investigation into the Development and Validity of Progressive Fitness Tests for Rowing and Young People

Name

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AN INVESTIGATION INTO THE DEVELOPMENT AND VALIDITY OF PROGRESSIVE FITNESS TESTS FOR ROWING, AND YOUNG PEOPLE

By

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For Mum, Dad, John and my friends for always being there.

"I believe that God made me for a purpose, but He also made me fast. When I run, I feel His pleasure."

(E.Liddell, 1924 Paris Olympics)

ABSTRACT

The aim of this thesis was to develop a new rowing based version of the multistage fitness test to be used on a concept II rowing ergometer in any gymnasium. It was also to quantify the physiological strain and asses the validity of the multistage fitness test on young people and its relationship between speed and strength variables.

In Study one, an incremental based rowing protocol (IRT) was developed. A Significant correlation was observed between a treadmill based VO_{2max} and the IRT for VO_{2max} ($r = 0.68$, SEE 4.7) and heart rate ($r = 0.76$, SEE = 5.8). In 41 gym users (35 females, 25 males) VO_{2max} values were significantly different between treadmill running (44.7. ± 6.5 $mL \cdot kg^{-1} \cdot min^{-1}$) and rowing (42.2 ± 7.3 $mL \cdot kg^{-1} \cdot min^{-1}$; $P < 0.05$). In all subjects maximum heart rate (HR_{max}) was significantly higher during the running VO_{2max} test (192.2 ± 9.6 $beats \cdot min^{-1}$) compared to the IRT (184.3 ± 10.6 $beats \cdot min^{-1}$; $P < 0.05$).

In study two, the validity of the MSFT was testing in young people. The MSFT had a significant relationship in girls ($n = 35$) between 10m sprint ($r = -0.48$; $P < 0.05$), 40m sprint ($r = -0.40$; $P < 0.05$), hand grip dynamometer strength ($r = 0.34$; $P < 0.05$) and pull dynamometer strength ($r = 0.49$; $P < 0.05$).Only 40 m sprint speed was significant in boys ($n = 25$) ($r = -0.57$; $P < 0.05$). Boys had no significance between the MSFT and 10m sprint ($r = -0.35$; $P > 0.05$), hand grip dynamometer ($r = 0.30$; $P > 0.05$) strength and pull dynamometer strength ($r = 0.29$; $P > 0.05$).

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During the completion of this thesis, work has been orally presented at the BASES student conference at London UEL and a poster presented at ICSEMIS conference in Glasgow. The oral presentation at the BASES student conference won BASES postgraduate oral award for best presentation. The results of the rowing study are now being used by Coachwise UK to develop a commercial indoor multistage fitness test for rowing.

This work is dedicated to all of my close friends. Thank you.

DECLARATION

The material contained within this thesis represents original work written by the author. The following published communications of work have been due to work contained within this thesis:

Metcalfe, A, J., Castle, P, C., Brewer, J. (2012) The development of a new incremental stroke rate based indoor VO_{2max} test for rowing- *Manuscript in preparation.*

Name of candidate: ALAN METCALFE Signature:

Date

Chapter I. Introduction

Exercise testing is regularly used in gymnasia to assess fitness, hospitals for monitoring progression during rehabilitation, schools for the observation of maturation and sports grounds for the assessment of elite sports performance. A variety of exercise tests can be used for these specific needs and population groups. Athletes and gym users use exercise tests to monitor their specific adaptations during a training programme whereas, hospitals use exercise testing to prescribe exercise and keep check on clinical populations. Schools also use fitness testing, most notably in the UK the 20m multistage fitness test (MSFT) to keep check on young people's health and growth.

It is because of this great demand in fitness testing that so many tests already exist and are used in several different situations. Both the British Association of Sports Science (BASES) and the American Colleges of Sports Medicine (ACSM) devote regularly updates and editions to their specific exercise testing guidelines. The BASES 'Sport and exercise physiology testing guidelines' focuses on more specific sporting event chapters whereas 'ACSM's guidelines for exercise testing and prescription' focuses on more of a clinical stand point.

This thesis is presented in the following chapters.

Chapter II provides a review of the literature surrounding sports and exercise physiology testing and more specific testing procedures. Also, the literature around the development of many of these tests is critical reviewed with a special focus on rowing specific tests. A brief look at the physiological factors that happen during maturation in young people is reviewed.

Chapter III provides detailed information around the methodology used within each experimental chapter (IV and V) and the pilot testing conducted to ensure a successful experimental project was taken forward.

Chapter IV presents the first study which developed a new rowing ergometer based fitness test to predict VO_{2max} which could be used by a regularly gym user with access to an audio headset.

Chapter V presents the second study which looked at the validity of the MSFT on 8-12 year olds from a local athletics club. Also, performance scores on MSFT were compared to strength and speed variables.

Chapter VI reviews the findings on the previous experimental chapters and looks towards the future direction after both studies.

Chapter II. Review of literature

2.1 Introduction

The aims of the following sections are to provide the reader with background information about relevant topics with regards to the experimental chapters. The first section (*section 2.2*) outlines the gold standard way of assessing aerobic fitness by maximal oxygen uptake. It also introduces the multi stage fitness test and economy during exercise. The next section (*Section 2.3*) goes into detail about the multi stage fitness test with its history and impact on specific sports. The impact of other types of fitness tests is then reviewed in the following section (*Section 2.4*) including intermittent tests and endurance tests. The following section (*sections 2.5*) give an overview of rowing including physiology, economy, velocity and heart rate responses. The mechanics of rowing is also reviewed (*Section 2.5)* in relation to the concept II rowing ergometer. Predicting athletic performance using fitness tests with a main focus on rowing is then reviewed (*Section 2.6*). As well as rowing, this thesis also takes a look at the validity of the multi stage fitness test in young people therefore, paediatrics has been reviewed (*Section 2.8*). Finally a short summary of each section and proposed solution is given (*Section 2.8)* with a hypothesis.

2.2 Maximal oxygen uptake

This first section looks at the discovery, development and theory behind VO_{2max} and what limits it including lactic acid and Tim Noakes central governor theory. Finally, we look at development of economy and how it influences athletes.

2.2.1 Original concept of VO_{2max}: the 'classic model'

VO_{2max} is the maximal amount of oxygen consumed in a minute. The results of a VO_{2max} test reflect a person's maximal physical capacity expressed as either litres (l/min) or millilitres ($ml \cdot kg^{-1} \cdot min^{-1}$). VO_2 at rest is around $0.251 \cdot min^{-1}$ but during exercise such as a VO_{2max} test, VO_2 can reach as high as $81 \cdot min^{-1}$ in male endurance athletes (Jones & Poole, 2005).

The original concept of the VO_{2max} was first researched in the early 1920's by A.V. Hill and colleagues (1922), publishing four papers entitled 'muscular exercise, lactic acid and the supply of and utilisation of oxygen'. They discovered that VO_2 increased in a linear fashion with increase in exercise speed until exhaustion, believing three factors limited VO_{2max} including arterial saturation, mixed venous saturation and O_2 capacity in the blood (Bassett, 2002). The first two factors can be defined as limited cardiac output, described by the flick equation-

$$VO_{2max}\ Q(CaO_2\text{-}CvO_2) \qquad [2.1]$$

Q is cardiac output, CaO_2 is the arterial oxygen content and CvO_2 is the venous oxygen content (CaO_2-CvO_2) which is also known as the arteriovenous oxygen difference. This 'classic' view for achieving VO_{2max} is when a reduction in cardiac output becomes the limiting factor caused by a reduction in oxygen transport from pulmonary diffusion into the mitochondria (Leveine, 2008; Suprway et al, 2012).All stages of the oxygen transport pathway including pulmonary diffusion and oxidative phosphorylation in skeletal muscle mitochondria have influence on an individual maximum uptake (Figure 2.1) therefore, if cardiac output was to increase (training adaptation) then all other pathways should increase too (Suprway et al, 2012).

The third factor is O_2 carrying capacity as another limiting factor of VO_{2max}. This was first demonstrated in 1976 by Ekblom and colleagues where they took 800ml of whole blood and re-infused it 8 weeks later to find an increase in O_2 carrying capacity, resulting in an 8% increase in VO_{2max}. Many of A.V Hill's original ideas have been supported for the past 60 years however, recently the question of 'what limits VO_{2max}?' has come under great scrutiny.

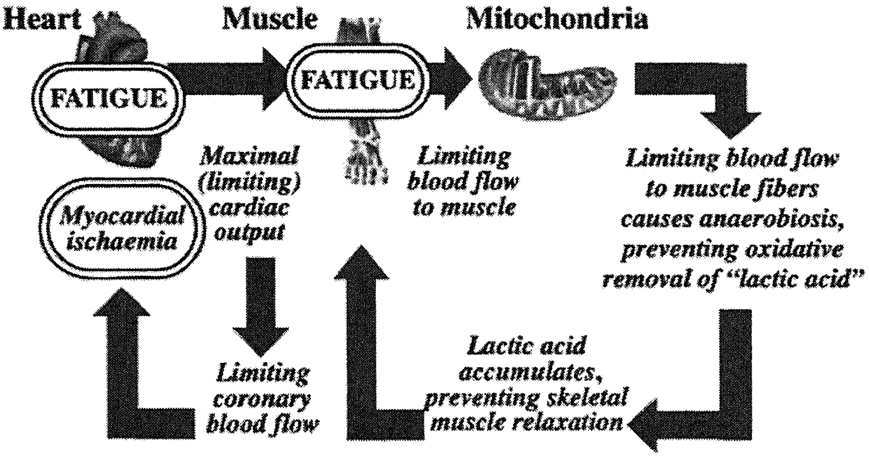


Figure 2.1. Classic model developed by A.V. Hill and Colleges in 1923 (Taken from Noakes, 2011).

Whether the cardiorespiratory system and/or skeletal muscle circulatory factors cause a limit in VO_{2max} is still a major unresolved question. Gonzalez-Alonso & Calbet (2003) attempted to identify the factors that limit VO_{2max} using heat stress as an intervention. They found that reductions in both skeletal muscle blood flow and oxygen delivery limited VO_{2max} achieved in humans. Following research by the same group (Gonzalez-Alonso et al, 2004), research then looked at both central and brain haemodynamic using stroke volume and venous return as their measures. They found that a reduction in stroke volume, causing a fall in oxygen delivery and uptake (before exhaustion) leads to a reduction in venous return to the heart.

Hill and colleagues (1923) also observed a plateau in oxygen consumption, describing it as ‘an apparent steady state’ (1923, p.156) in two of their four subjects which was considered to be due to oxygen debt (Spurway et al, 2012), now known as the ‘plateau phenomenon’. It was quickly adopted that the observation of an incremental exercise plateau indicated the maximal physiological ceiling (Figure 2.2). Since, there has been a debate as to if the observation of a plateau represents a ceiling in maximal oxygen uptake.

The observation of a plateau at the end of a VO_{2max} test has been part of the traditional criteria for achieving VO_{2max}, commonly accepted when a change in VO_2 at VO_{2max} < 150 ml/min is observed (Taylor et al, 1955) as well as including respiratory exchange ratios (RER), heart rate (HR) and blood lactate B[la] concentrations. There have been criticisms of the plateau being part of the criteria for some time which has led to the emergence of a verification phase to confirm a true VO_{2max} is obtained (Niemela et al. 1980; Midgley & Carroll, 2009). This phase involves exercising about 10 minutes after exercise at around one stage higher than achieved on an incremental test protocol for as long as possible. This has been used and verified using cyclists (Niemela et al. 1980) runners (Midgley et al. 2006) and middle-aged or older adults (Dalleck et al. 2012).

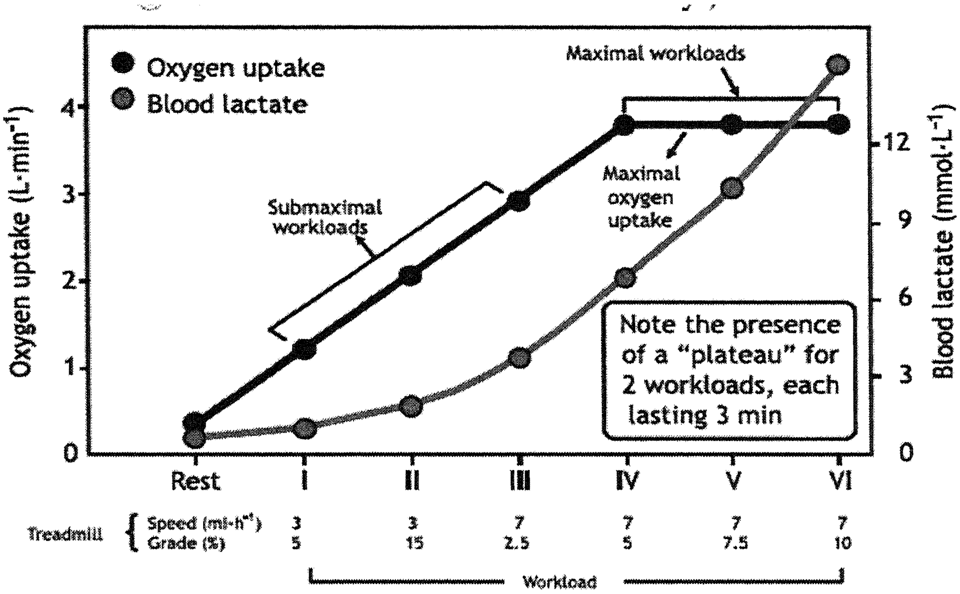


Figure 2.2. Graphic showing the 'plateau phenomenon' during maximal oxyegn uptake. (Taken from Mitchell & Blomqvist, 1971)

The optimal data averaging and duration of VO_{2max} testing has also recently, come under great scrutiny. Breath-by-breath averaging of data is the most sensitive method of analysing data however, researchers still use data averaging of 10,15,30 and 60 seconds (Robergs, 2001). It has been suggested that this interpretation of gas exchange analysis has caused the incidence of a plateau in VO_2 at VO_{2max} (Astorino et al. 2005) using the traditional criterion of $VO_2 < 150$ ml/min (Taylor et al.

1955). It has therefore, been suggested that breath-by-breath or shorter sampling intervals (15sec) are used (Astorino et al. 2000; Astorino et al. 2005).

2.2.2 Lactic acid

Intense incremental exercise produces high levels of blood lactate (B[la]) with peak lactate levels reaching up to around 12mmol. For most of the 20th century, lactate was believed to be the dead-end waste produce post exercise due to oxygen debt (hypoxia), causing muscle fatigue and acidosis. Recently however, this hypothesis has re-evaluated as a factor of muscle fatigue in a lactate shuttle hypothesis. Brooks et al (1985) proposed a lactate cell-to-cell shuttle that occurs in skeletal muscle. During anaerobic metabolism both anoxia (elevated levels of blood oxygen, opposite to hypoxia) and dysoxia (O_2-limited oxidative phosphorylation) are present with lactate. Dysoxia over the past 35 years has been seen to be the primary cause in the increase of lactate production during submaximal exercise in the muscle and blood (Connett et al, 1986).

During intense exercise, muscle produces lactate rapidly while lactate clearance is slow, causing an increased build-up of lactate in the muscle. Lactate escapes from the glycolytic muscle fibres into the circulation, most being oxidized in neighbouring oxidative muscle fibres (Brooks, 2000). Evidence has been shown to suggest that the heart (Chatham et al 1999) uses lactate for as much as 60% of the substrate utilization as well as the brain. Ide & Secher (2000) showed evidence that the brain uptakes a net lactate during intense exercise as well as up to 30min post exercise.

The cell-to-cell shuttle (Figure 2.3), first proposed by Brooks et al (1985) provides a basic framework for the understanding of lactate metabolism (Gladden, 2004). Blood provides the link for the cell-to-cell shuttles within the body. Lactate and hydrogen (H^+) are moved out of contracting muscle and gain access to the blood stream and across the endothelial cells by MCT1 and MCT4 (Monocarbohyrdate transporters). Once in the circulatory system, lactate travels to all inactive and active muscles, liver and heart. MCT1 then diffuses into the mitochondrial matrix where the conversion of lactate to pyruvate would begin.

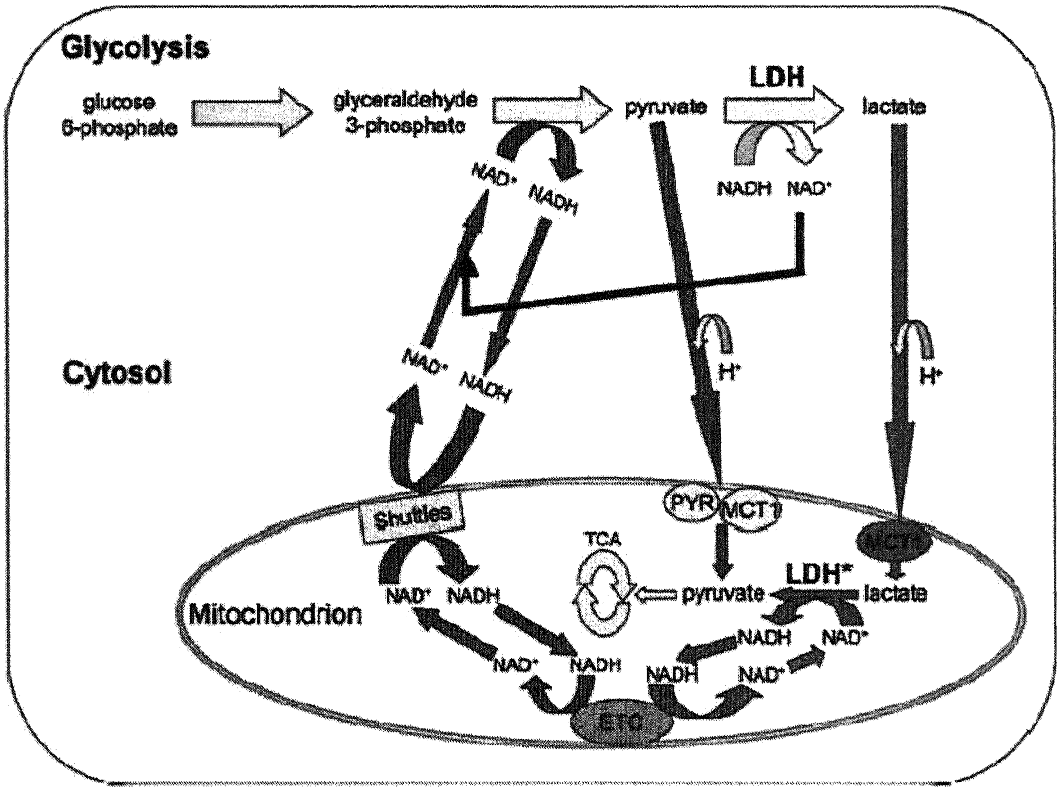


Figure 2.3. Intraceullar lactate shuttle (Re-drawn from Gladden, 2004).

2.2.3 Central governor model

Hill quoted a 'governor' (Hill et al, 1924, pp.161-163) as a possible mechanism for the limit of VO_{2max}, an idea which has been developed by South African, Tim Noakes, called the central governor model (Noakes & St Clair Gibson, 2004). The central governor model proposes that the brain stops the body exercising when homeostasis cannot be maintained at very high work rates therefore, the VO_2 achieved at max does not truly reflect the body's maximal oxygen uptake. The body maintains a reserve to ensure it doesn't break down, possibly causing death.

Several recent studies have shown that different testing methods can produce submaximal values of maximal oxygen uptake (Beltrami et al, 2012., Mauger & Sculthorpe, 2012), a finding which challenges A.V Hills classic model (Noakes, 2012). Beltrami and colleagues observed higher oxygen consumption values during a decremental exercise protocol compared with an incremental exercise protocol. They suggest that their results show that the observation of a plateau during incremental exercise does not represent a ceiling in cardiovascular capacity and therefore, cannot be used as a criterion for reaching maximal oxygen uptake. Similarly, Mauger & Sculthorpe (2012) used an RPE based incremental exercise test which allowed the subjects to self-pace themselves throughout the test (5x2 min stages at RPE of 11,13,15, 17 and 20). They observed significantly higher VO_{2max} values in the self-paced version (SPV) than the traditional VO_{2max} test. The researches were unsure of the mechanisms which allowed for a higher VO_{2max} however, suggest a number of reasons due to the self-paced nature of the test including efficient use of muscle mass and a reduction of type II muscle fibres therefore, greater oxygen-dependant type I muscle fibre activation. Both these two recent studies show that, using novel exercise protocols, higher VO_{2max} values can be observed suggesting that the traditional VO_{2max} test fails to elicit a true maximal oxygen uptake value.

2.2.4 VO_2 economy

Economy, in running terms, is the relationship between VO_2 and running velocity (Daniels, 1985) and is influenced by core temperature, muscle stiffness, muscle metabolism, body composition, muscle fibre-type and running technique (Saunders et al, 2004). The concept of running economy was again, established by A.V Hill in the early 1920's. Hill and co-workers not only found that O_2 cost increases with speed but also that a variation in biomechanical movement affects economy rather than muscular efficiency (Bassett, 2002).

During submaximal exercise a linear relationship can be seen between VO_2 and vVO_2 (Velocity at VO_{2max}). It is also affected by the efficiency of an athlete which is determined by work done and energy expenditure.

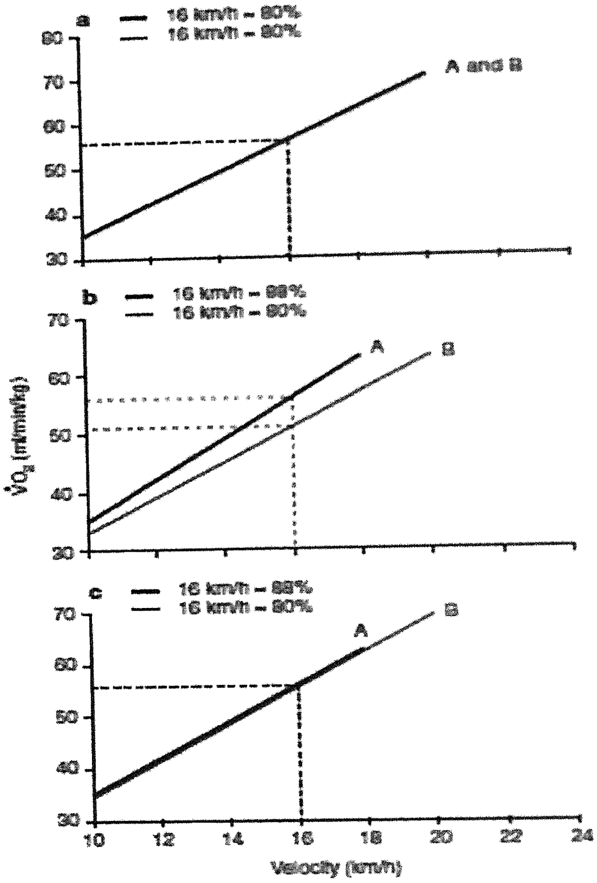


Figure 2.4. The effect of VO_2 on running economy in two different runners: (a) Identical VO_{2max} and running economy between runners A and B; (b) Difference between time to exhaustion and running economy however, identical VO_{2max}.; (c) Running economy is identical but VO_{2max} is higher in runner B. (Taken from Bosquets et al, 2002).

Running economy is measured by steady-state VO_2 at submaximal running speeds and respiratory exchange ratio (RER) (Saunders et al, 2004). During laboratory testing, trained subjects appear to be more economical than non-trained as well as a etter display in economy among elite runners than sub elite (Figure 2.4) and has een described as they ‘forgotten factor in elite performance’ (Foster & Lucia, 2007). Several interventions can be employed by athletes in their training programs to mprove their running economy. These are strength training, altitude and heat acclimation(Saunders et al, 2004).

In Summary, VO_{2max} is the gold standard in fitness testing and is believed to represents the maximum a human can physical perform but, has recently been challenged. VO_{2max} naturally increases through during growth (*See section 2.6*) and can also be increased through the correct endurance training.

2.3 Multistage fitness test

The multistage fitness test (MSFT), also referred to as the bleep test, PACER test and 20m shuttle run is an indirect way of predicting VO_{2max}. The test is easy to administer to a large scale group of participants as it requires little equipment and limited experience to a wide participant group range of 24-70 $ml \cdot kg^{-1} \cdot min^{-1}$.

2.3.1 History of multistage fitness test

The development of the test was first published by Leger & Boucher (1980) as a 20m multi stage track test, later developed into the maximal multi-stage 20 m shuttle run test (Ledger & Lambert, 1982) to predict maximal oxygen uptake. Ledger & Lambert (1982) found a correlation between the VO_{2max} using retro-extrapolation method; r = 0.84 (n 91) with a standard error of 5.4 $ml \cdot kg^{-1} \cdot min^{-1}$.

The validity of the test was questioned by Paliczka et al (1987) who assessed the validity using a 10km time trial performance and later Ramsbottom et al (1988) using a 5km time trial performance. Both studies found time trial performances correlated with MSFT performance. Paliczka et al (1987) found high correlations between both MSFT Vs. VO_{2max} (r = 0.93), MSFT Vs. 10km (r = 0.93) and VO_{2max} Vs. 10km (r = 0.95) however, only 9 male subjects (Age 35.4 ± 5.8; 59.0 ± 9.9 $ml \cdot kg^{-1} \cdot min^{-1}$) were used. Ramsbottom et al (1988) used a far greater participant base (n = 74; 36 men, 58.5 ± 7.0 $ml \cdot kg^{-1} \cdot min^{-1}$ and 38 women, 47.4± 6.1 $ml \cdot kg^{-1} \cdot min^{-1}$). Again, similar to Paliczka et al (1987), significant correlations were found between MSFT Vs. VO_{2max}

(*r* = 0.92), MSFT Vs. 5km (*r* = -0.96) and VO_{2max} Vs. 5km (*r* = -0.94). Results from both studies suggest that the MSFT not only accurately predicts VO_{2max} but also gives a strong indication of 10km performance in men and 5km performance in both men and women.

Ledger et al (1988) later validated a 1minute stage version of the MSFT as children found the 2 minute stage MSFT psychological boring. Using 188 boys and girls aged 8-19, Ledger et al (1988) conducted a test retest reliability study of the 1 minute stage version which was found to be reliable (*r* = 0.95) with no significant differences being observed.

The test originally started at 8.5Km/h for 2 minute stages, later, decreased to 1 minute stages (Ledger, 1984) with increments of 0.5 km/h each minute. This is different to some protocols used by fitness testing batteries including Eurofit and PACER which have a starting speed of 0.8km/h, increasing to 9 km/h in the second stage. Increments of 0.5 km/h are then seen every minute for the rest of the test (Tomkinson et al, 2003). It has been noted by Tomkinson et al (2003) that few authors are aware of these protocol differences and therefore, incorrectly reference the original Leger & Lambert (1982) paper, described with 2 minutes stages whereas, the protocol actually used would differ.

There is a variation in worldwide MSFT performance, shown by Olds et al (2006) in a meta-analysis of 109 studies in 37 different countries. The analysis suggested that poor performance in the test was not just related to obesity but also a countries average temperature. In that study, United Kingdom was ranked 22nd out of 36 countries and a more detailed look at the data showed that only one study from 1988 was completed in England (Armstrong et al, 1988), the rest were from Wales, Scotland and the majority from Northern Ireland (Sandercock et al, 2008).

2.3.2 Reliability of multistage fitness test

The repeatability of the MSFT in 30 active young men (21.8 ± 3.6yrs) were used to see if the test is valid (Cooper et al. 2005). They found no significant difference between in mean scores between the test re-test anaylsis (Xdiff= -0.4 $ml \cdot kg^{-1} \cdot min^{-1}$), similar to the original results from Leger et al (1988) suggesting a good repeatability and validity. They did however, find VO_{2max} was underestimated compared to laboratory VO_{2max} results (*For more see section 2.3.4*). Cooper et al (2005) also applied 95% limits of agreement to their results, which was considered to be repeatable and concluded that although the MSFT is not valid for accurate prediction in VO_{2max} it is a well-established field test.

2.3.3 Multistage fitness test on specific athlete groups

Various studies have looked at the MSFT on performance in different athletic groups. The test has been performed by English first and second division soccer players during their pre-season training (Davies et al, 1992) and it has been suggested that the test should be used for talent identification and selection in developing players (Castagna et al, 2010b) along with the Yo-Yo IR1 test. The Yo-Yo intermittent endurance test has become a more popular form of fitness testing team based sports players (*More information see section 2.4.3)* (Aziz et al, 2005).

2.3.4 Critic of multistage fitness test

As already mentioned in section 2.3.2, results from several studies suggest that the MSFT under predicts VO_{2max}. Castanga et al (2010a) found the predicted VO_2 from the MSFT was significantly lower than measured VO_{2max} test score (32.7 vs 40.1 $ml \cdot kg^{-1} \cdot min^{-1}$) however, this was in twenty-six young soccer players with an average age of 12.1. They suggest that distance covered during the MSFT was a better predictor of exercise performance than the nomogram due to age dependant performance. Other studies however, have found an under prediction in an older age group population with Cooper et al (2005) subjects all around 21, finding an under estimation in predictive VO_{2max} (*Previously in section 2.3.2*).

Different equations have been created depending on gender (Stickland et al, 2003) to give a more accurate predicted measure of VO_{2max}. Stickland et al (2003) directly measured VO_{2max} and compared the results of both Leger et al (1988) ($Y = -24.4 + 6.0$ Maximal aerobic speed) and Leger & Gadoury (1989) ($Y = -32.678 + 6.592$ Maximal aerobic speed) prediction equations. Both equations were predicted significantly lower than directly measured VO_{2max} in females ($Y = 2.85 X + 25.1$) and males ($Y = 2.75 X + 28.8$) where X is the last half-stage of the shuttle run complete.

In summary, the MSFT has become a very popular way of predicting VO_{2max} in schools and among the emergency services. It is a practical way of assessing fitness without the need for expensive equipment or long periods of time. It does however, come with criticisms in the accuracy of its predictive VO_{2max} outcome. Putting this aside, the test still works regardless of VO_{2max} score. Participants with the lowest VO_{2max} scores finish first and the highest VO_{2max} scores finish last.

2.4 Fitness tests

In this section we look at different sports specific fitness tests from the past 50 years mainly focusing on endurance tests unlike sprint, agility or power tests. This section also looks at a number of fitness tests which have been developed from the MSFT such as the Yo-Yo intermittent endurance test and the 10m swimming MSFT.

2.4.1 General Fitness tests

The Cooper 12 minute run and the MSFT are the most commonly known fitness test. Both these tests can accommodate for large numbers of participants and provide an estimation of VO_{2max} for every participant.

Cooper's 12 minute run was developed in 1968 when 115 US air force officers complete a VO_{2max} test and a 12 minute run ($r = 0.87$). A significant relationship was found and a prediction table was created based on the distance complete in the 12 minutes (Cooper, 1963). A recent study looked at the reliability of the Cooper 12 minute run test and showed that VO_{2max} scores were underestimated in lower VO_{2max} scores and overestimated in higher VO_{2max} scores achieved (Penry et al, 2011). They conclude that the MSFT would be a more useful tool for the prediction of VO_{2max} because of its mean bias across all fitness levels (*For a detail of the MSFT see the previous section 2.3*)

In 1982, Italian scientist Conconi developed a test using heart rate to predict a runner's anaerobic threshold (Conconi et al, 1982), later called the Conconi test. The test was based upon a deflection point during an incremental exercise test in the heart rate/work intensity relationship. Conconi discovered that the deflection point matched lactate measurements for anaerobic threshold and running velocity. Heart rate could therefore be used in a non-invasive field test and predict a runners anaerobic threshold. The test was then modified for other sports including canoeing, cross-county skiing, cycling, roller skating, ice skating, walking and rowing (Droghetti et al, 1985; Bourgois & Vrijens, 1998).

From a practical sense, Conconi's test was a very popular training resource however, since its creation the test has been heavily criticised for several reasons. Firstly, a deflection point in heart rate cannot always be observed in some subjects and therefore, questions the reliability of Conconi's test. Secondly, the anaerobic threshold heart rate in Conconi's test has a low correlation between other studies which look at anaerobic threshold suggesting that there is little validity in the test. 12 years after the first test was published, Conconi replied to the criticisms made suggesting that many studies assessing the test have resulted in poor methodologies and incorrect exercise protocols in performing the test (Conconi et al, 1996). Conconi states that the original test published was based upon a ramp based protocol instead of a stepwise fixed distance test protocol.

The validity of Conconi's test on other sports other than running has also been heavily criticised. The test has been adapted for rowers and was investigated

Bourgois & Vrijens, 1998) to assess the validity of the Conconi test in rowing ergometry using 10 experienced rowers. In some subjects, a heart rate deflection point was very hard to be determined therefore, Bourgois & Vrijens (1998) questioned the validity of using the Conconi test which has been questioned previously in the literature (Droghetti, 1986). They concluded that Conconi's new proposed methodology (Conconi et al, 1996) resulted in overestimation of optimally intensities for endurance training on a rowing ergometer and therefore, not a valid form of monitoring training in young rowers (Bourgois & Vrijens, 1998).

2.4.2 Battery of fitness tests

A variety of fitness tests can be grouped together to create fitness test batteries. Many batteries exists with the most popular being Fitnessgram in the USA and the Eurofit and ALPHA test in Europe (Ruiz et al, 2010). These batteries provide a feasible and safe way to assess fitness in sports clubs and in schools during physical education lessons.

The fitness tests included in these batteries have been considered reliable markers of health related fitness. The MSFT is considered a reliably measure of cardiorespiratory fitness (See Section 2.3.2), hand grip strength (See section 2.6.7) and standing long jump have been considered reliable measures of musculoskeletal fitness and body fat can be reliably measured using BMI, skinfold thickness and waist circumference (Ruiz et al, 2010).

2.4.3 Intermittent specific fitness tests

More specific fitness tests have been development for intermittent sports. The Yo-Yo intermittent recovery test (Yo-Yo IRT), inspired by Leger's MSFT was designed by Jens Bangsbo and is now one of the most popular test used in the literature when testing sports teams including soccer, rugby, Australian football and basketball (Bangsbo et al, 2008). The Yo-Yo test is similar to the MSFT where 2x20m shuttles are ran however, a 10-second period of active recovery is given between each shuttle creating the intermittent section. There are also two types of intermittent tests which can be seen in figure 2.5. The Yo-Yo IRT1 which starts at a lower speed lasting around 10-20 minutes, in addition the Yo-Yo IRT2 which starts at a quicker speed meaning the test is over quicker, around 5-15 minutes. Anaerobic energy contribution is increased during the Yo-Yo IRT2 whereas the Yo-Yo IRT1 induces a greater aerobic component (Bangsbo et al, 2008).

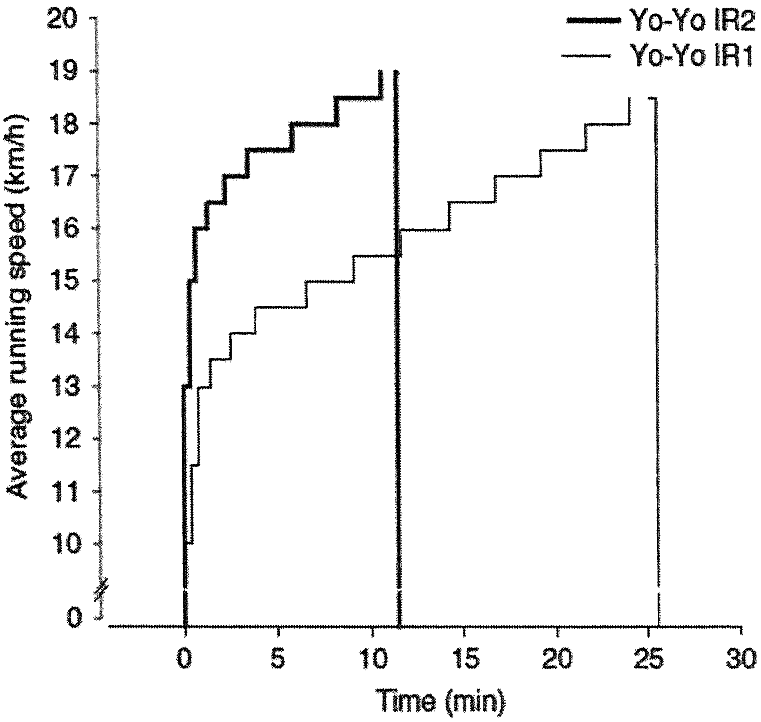


Figure 2.5. Yo-Yo intermittent recovery test protocols IR1 and IR2 (Taken from Bangsbo et al, 2008)

The Yo-Yo IRT has been regularly used in younger football players around the ages of 11-18, which means a different physiological response would be present creating doubt on the validity of the test in older players as young players, on average run less distance at around 6-9km. Wong et al (2011) tested the Yo-Yo IRT on sixty two young soccer players with an average age of 13.7 and found a strong correlation (*r* = 0.63) between the Yo-Yo IRT and VO_{2max}, reducing doubt over the tests validity in young players. Another fitness test designed to simulate soccer is the Loughborough intermittent shuttle test (LIST) (Nicholas et al, 2000). This test is split into two parts, A and B and replicates a series of walking, jogging, running and sprinting actions over 20 meters, similar to match performance. In 7 male games players (VO_{2max}: 59 ± 1.9 $ml \cdot kg^{-1} \cdot min^{-1}$) a similar physiological response was observed as well as distance covered in a professional match. A similar amount of sprints were also included providing a strong field test which can again be performed in a gym or training environment.

2.4.4 Sports specific fitness tests

There are many fitness tests which have been developed for specific sports players. Girard et al (2006) focused on developing an incremental field test for tennis players. The test was designed to mimic the kind of requirements needed for the game. The test was based around stages from a central base and shuttle runs, increasing in speed from the central base to six targets located around the court. A 15 second passive recovery was given between each stage. The set of targets were placed in front (Offensive), side (Natural) and behind (defensive) and were performed randomly. Each time the participant arrived at a target they were required to performance a powerful stroke that would be used in competition before returning to the base. All testing was controlled via visual and audio feedback. The new tennis test was compared to a treadmill based VO_{2max} test in 9 junior male competitors. Physiological variables were not different between the test at sub maximal intensities but the authors did find that VO_{2max} values from the laboratory measures were significant lower than predicted in the tennis test. It was concluded that treadmill testing is not relevant for junior tennis players rather, the new tennis test provides a better predictor of successful tennis performance.

Several fitness protocols exist for the assessment of the aerobic energy system during swimming, in the BASES exercise prescription guidelines (Thomson & Taylor, 2007). In 2000, Rechichi et al (2000) developed a swimming based 10m MSFT using 22 male and 22 female competitive water polo players. Using a pool, the swimmers swam at 0.9 m.s-1 for the first level, increasing my 0.05m.s-1 each level. The levels lasted 1 minute each. Using a between scores test, no significant differences was observed ($r = 0.99$, $P > 0.05$) and a strong correlation was also observed ($r = 0.88$) between the number of shuttles complete and measured VO_{2max} using a tethered swim. The research shows that a multistage shuttle swim test can be practically complete and accurate predict VO_{2max} in water polo players.

In summary, fitness tests are a useful tool for coaches and trainers to assess the fitness of sports performers with a variety of sports specific tests available. They are also useful for the assessment of the general adolescent, keen on improving or monitoring their fitness at the gym to ensure a healthy lifestyle is maintained.

2.5 Rowing

This section provides the reader with knowledge of the physiological and biomechanical requirements for rowing. Olympic rowing events take place over 2,000m with variations in boat size, type of rowers and event category. There are two categories, lightweight and open. In the lightweight category men should be 70kg or less and women 57kg or less. In the open category no limits apply (Mikulic et al, 2009) meaning an increase in body build is an advantage (Shephard, 1998).

2.5.1 Rowing physiology

The 2,000m rowing distance requires high levels of both aerobic and anaerobic elements. The anaerobic energy system is required for the initial spurt while the aerobic energy system is used for about 70% of the time taken to complete a 2,000m race (Shephard,1998). Aerobic power and muscle endurance does however, varies during the season by around 10%. Females are on average 16% slower than males during 2,000m rowing therefore, women spend a longer time on the water (Yoshiga & Higuchi, 2003a,b). A female rowers VO_{2max} is also about 20-27% lower than that of a male rower (Jensen, 2001). A longer 2,000m time and lower VO_{2max} suggests that female rowers require a longer aerobic energy capacity than anaerobic to ensure a steady consistent pace throughout a race.

As well as performance values, relationships can been seen among successful rowers and their specific physical traits. Successful rowers tend to be more mesomorphic than endomorphic with long lower and upper extremities (Slater et al, 2005). In the Australian rowing championships, average male body mass was

71.2Kg with a height of 180.7Cm. Females were 57.9Kg with an average height of 170.3Cm (Slater et al, 2005). Due to these large body dimensions, VO_{2max} is often higher in rowers whereas in other sports such as long distance running, body mass would hinder exercise performance (Secher, 1993., Yoshiga & Higuchi, 2003b). Several studies have found a relationship between body mass and VO_{2max} (Jensen, 2001., Cosgrove et al, 1999) as well as body mass and 2000m rowing performance (Cosgrove et al, 1999., Yoshiga & Higuchi, 2003c). A body weight reduction of 5.9% (61.3kg-57.0kg) and 7.6% (75.6kg-69.8kg) has been observed in female and male lightweight rowers respectively however, no change was seen in fat-free mass (Morris & Payne. 1996).

It is thought that increased body size in rowers increases the respiratory function. Maximum expiratory volume (VE_{max}) is related to body size and fat-free mass (Yoshiga et al, 2003b) suggesting that the bending of the body during rowing did not impair respiratory performance. It has been proposed that respiratory function in rowers is reduced due to the cramped position of the rowing stroke (Cunningham et al, 1975). Several studies have used inspiratory muscle training as an intervention to improve minute ventilation with peak rates observed at values greater than 200 $L \cdot min^{-1}$ (McKenzie & Rhodes, 1982). Voliantitis et al (2001) showed that 11 weeks inspiratory muscle training significantly improves rowing performance in female competitive rowers during a 6-minutes all-out effort however, Riganas et al (2008) failed to find any significant differences in VO_{2max} and 2,000m rowing times. More recently, Forbes et al (2011) found inspiratory muscle training to improve muscle strength but not 2,000m performance in 21 rowers during a 10 week training programme.

2.5.2 Cardiovascular response during rowing

Heart rate (HR) and cardiac output (Q) increases linearly throughout progressive incremental exercise. In a meta-analysis, Pluim et al (1999) found HR increases during rowing to nearly 190 Bpm with systolic blood pressure peaking at around 200 mmhg. The maximum heart rate (HR_{max}) usually achieved during maximal exercise is 220 Bpm minus your age therefore, a 30 year old would expect to have a maximum heart rate of 190 Bpm. HR has been used to predict % VO_2 in running and arm exercise (Rotstein & Meckel, 2000). Their prediction overestimated VO_{2max} when calculated from HR_{max} in arm crank exercise from actual VO_{2max} measured. Rotstein & Meckel's (2000) study suggested that prediction of VO_{2max} from HR_{max} was more accurate in running than arm crank exercise.

One reason why Rostein & Meckel (2000) may have struggled to predict VO_{2max} from HR_{max} is that HR appears lower during incremental arm exercise than running. Yoshiga et al (2002a) found in 55 males (Av age 21 ± 3yrs), HR to be lower during rowing than in running (Figure 2.6), respectively (194/198 Bpm). They suggest that a smaller HR response was found in rowing due to the seated position of the rowing ergometer unlike the upright position of a treadmill. The seated position increases the involvement of muscle mass causing an increase in venous return and an elevated central blood volume. The data from Yoshiga et al (2002a) were however, all male subjects around 21 years of age. Following these findings, Yoshiga and colleagues future research looked into the HR response of older men (Yoshiga et al, 2003d) and introducing female subjects (Yoshiga et al, 2003a).

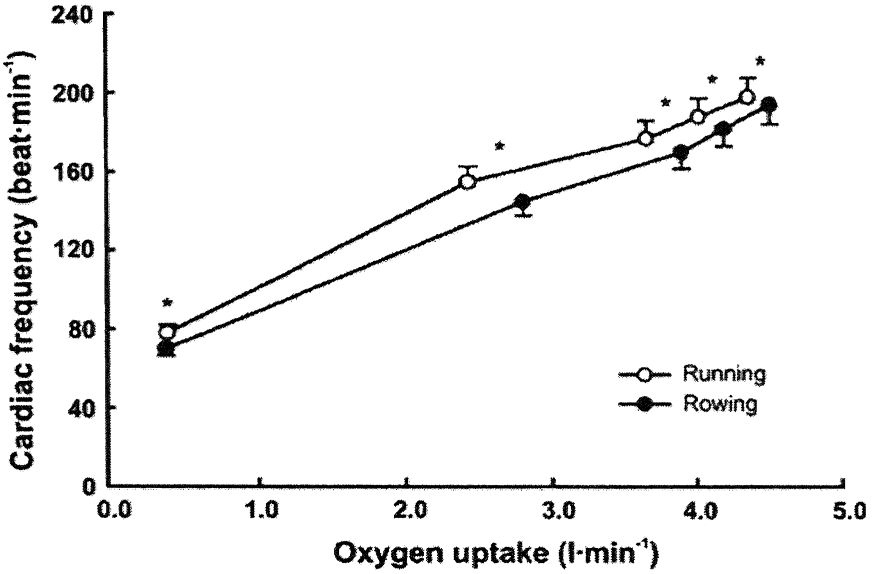


Fig 2.6. Difference in cardiac output between running and rowing tests. (*$P < 0.05$)

(Taken from Yoshiga & Higuchi, 2002a)

Again, Yoshiga et al (2003b) found HR_{max} to be lower in rowing than running. They also found no gender difference in HR_{max} in both rowing and running. They did find that VO_{2max} and VE_{max} related to both body size and fat-free mass in both male and female subjects (*see section 2.5.1*).

Although HR has been found to be lower in rowing than running, HR and cardiac output, at similar levels of oxygen consumption has been found to be significantly higher on a rowing ergometer than a cycle ergometer (Rosiello et al, 1987). Rosiello et al (1987) study aimed at describing the cardiovascular response of rowing and compared Q, HR and SV during both cycle and rowing ergometer exercise. A comparison between rowing and cycling was chosen because an individual's body weight is supported by both exercise modes and previous research has observed similar results (Wiener et al, 1995). No significant difference was observed between Q however, HR was significantly higher and SV significant lower on the rowing ergometer. They concluded that the mechanism behind the difference is unclear however, as previously described, venous return to the right side of the heart maybe a possible defect during rowing resulting in this decrease.

2.5.3 Stroke rate and velocity

The stroke rate (strokes/min) of a rower is the number of strokes achieved in one minute (Soper & Hume, 2004). During a 2,000m race in a single scull, stroke rates can range from 32-38 strokes/min with maximum stroke rates achieving 38 strokes/min at the start and end of a race (Steinacker, 1993).

The stroke can be broken down into two key phases during rowing called the stroke phase and the recovery phase. The stroke phase is when the blades are in the water and the rower exerts a force on the oars which pulls the boat forwards. The recovery phase is when the blades are out of the water and the rower is relaxed, moving back into position to pull again (Hofmijester et al, 2007a). The harder the stroke exerted from the rower, the greater the power.

As a rowers stroke rate increases, other biomechanical factors are affected such as a boats velocity. A rowing boats velocity, from a biomechanical perspective, can be described as the product of stroke length and stroke frequency. In order to improve mean velocity rowers must develop technical skills and technique as well as maintaining a high power output (Hofmister et al, 2007a). A significant relationship has already been seen between an increase in stroke rate and an increase in boat velocity ($r = 0.66$), observed during the drive phase (Martin & Bernfield, 1980). Martin & Bernfield filmed eight members of the US Olympic team at stroke rates of 37, 39 and 41 to look at the effect. The found as boat velocity increased so did the application of force in the drive phase.

More recently, Hofmijster et al (2007b) has looked at the relationship between mechanical power and stroke rate in a single scull with male rower's averaging around 500W for mechanical power over an average 7 minutes. Hofmijster et al, (2007b) results showed that mechanical power increases with higher stroke rates, agreeing with Martin & Bernfield (1980) previous findings on boat velocity. McGregor et al (2004) also found a change in force production as rowing intensity increased. More importantly, McGregor used lower stroke rates of 17-20, 24-28 and 28-36 and still found the same findings however, unlike Martin & Bernfield (1980) the research was conducted on a concept II rowing ergometer.

2.5.4 Concept II rower

The concept II ergometer is a popular rowing ergometer that can be found in many gymnasia up and down the UK. Rowing ergometers are used by elite rowers for off season training, recreational rowers for fitness in a gymnasia and scientists for research. Unlike on-water rowing, ergometer rowing requires less knowledge on the rowing technique (Mikulic et al, 2009) therefore, can be used for both elite and recreational standards alike.

Several models of the concept II rowing ergometer have been marketed. One concern is that scientists will find different physiological responses when testing between two different models therefore, Volger et al (2007) tested to see if there were any differences between the model C (IIC) and D (IID) models, introduced to the commercial market in 2003. They could find no difference in any physiological response including power output, oxygen consumption, rowing economy, heart rate and blood lactate during a progressive incremental test. Although Volger et al (2007) used experience rowers they only had 8 participants (6 men, 2 women) putting doubt on the reliability of their results. A bigger participant number is required for greater validity of these results.

The concept II rower is not the only rowing ergometer used in professional rowing and for scientific research. Results from the RowPerfect ergometer have also been validated for use in off water training (Elliot et al, 2002).

2.5.5 Predicting rowing performance

Many studies have attempted to predict rowing performance using a variety of different predictor variables. These predictor variables include VO_{2max} (Secher et al, 1982., Kramer et al, 1994., Ingham et al, 2002), heart rate (Lakomy & Lakomy, 1993., Huntsman et al, 2011), critical velocity (Kennedy & Bell. 2000., Kendall et al, 2012), anthropometric data (Russell et al, 1998., Bourgois et al, 2001), power output at B[la] of $4mmol \cdot l^{-1}$ (Izquierdo-Gabarren et al, 2009) and 2,000m rowing performance (Ingham et al, 2002).

Recently, Huntsmen et al (2011) attempted to produce a rowing-specific aerobic capacity test that could easily be used in the field. Because of the already strong relationship between VO_2 and Heart rate, they measured sub maximal peak heart rate at the end of every stage. Seven stages, starting at 200W for women and 250W for men, increased by 50W every 2 minutes with a 30 seconds break in between for

B[la]. They found that VO_{2max} and predicated VO_{2max} using heart rate was more accurate in men (r = 0.73, P < 0.0001) than in women (r = 0.57, P < 0001). One suggestion in modifying the test is to remove the 30 seconds break so that athletes have a more fluid incremental test. Another is to decrease the stage increments from 50W down to 25-30W for women. The studied showed that heart rate can be used in men as a predictor of rowing performance however, many complications lie when developing rowing fitness tests.

Other than heart rate, critical velocity has recently been popular in predicting VO_{2max} in running, cycling and now rowing (Kendall et al, 2011., Kendall et al, 2012). Critical velocity is the amount of velocity a person can maintain during exercise, without fatigue and therefore, correlates well with maximal lactate steady state and ventilatroy thresholds. The work of Kendall et al (2012) used 35 female colligate rowers in two incremental VO_{2max} tests on a concept II rowing ergometer to examine the relationship between VO_{2max} and critical velocity. The results were developed into a regression equation to predict VO_{2max} which showed a positive correlation between critical velocity and VO_{2max} (r = .75, P < 0.001). Kendall et al (2012) results suggest that critical velocity can be used to accurately predict VO_{2max} in female rowers but the population was young (age 19.2 ± 3 years) therefore, additional studies are required to validate this method and equation in older population groups.

Anthropometric data measures such as height, weight and body composition has become a very popular way of predicting rowing performance. Some of the simplest measures including standing height (r = 0.81, P < 0.001). Body mass (r = 0.85, P <

0.001) and free fat mass ($r = 0.91$, $P < 0.005$) have also all been strongly correlated to 2,000m rowing performance (Yoshiga & Higuchi, 2003a).

Data has not just become performance based but also used as a success predictor in junior rowers. Lawton et al (2010) looked at several variables including anthropometrics, muscle strength and endurance which count for 2,000m rowing ergometer performance and found that both upper-body strength and endurance were potential performance measures. This supported the original work by Russell et al (1998) who looked at metabolic, anthropometric and strength variables in relation to 2,000m rowing performance in elite school boys. Body mass ($r = -0.41$), VO_{2max} ($r = -0.43$) and knee extension ($r = -0.40$) were all correlated to 2,000m rowing performance ($P < 0.05$) and they concluded that anthropometric measures alone were the best predictors of performance ($r = 0.82$). Riechman et al (2002) also observed significant correlations between 2,000m rowing performance in 12 competitive female rowers. Several measures including height ($r = 0.815$), mean power ($r = -0.870$), maximal power ($r = -0.847.$), minimal power ($r = -0.890$), VE_{max} ($r = -0.624$) and VO_2 at lactate threshold ($r = -0.765$). All significantly correlated however, age ($r = -0.159$), body mass ($r = -0.508$), fat mass ($r = -0.308$), fat mass percentage ($r = -0.166$) and most importantly VO_{2max} ($r = -0.108$) did not significantly correlate with 2,000m performance.

More recently, three dimensional body scanning technology has been used to measure anthropometric data. Schranz et al (2012) compared traditional anthropometric body measures with new three-dimensional technology to suggest which method and selected variables are best for predicting 2,000m performance in 257 junior female rowers and 243 junior male rowers. Although the new technology of 2D and 3D scanning provided the best predictors of rowing ergometry performance, standard measures such as height, body mass and leg length still produced the strongest individual predictors.

In summary, rowing presents a very different form of endurance exercise compared to running and cycling. Whereas running and cycling are predominantly dependant on lower body strength and endurance, rowing is a whole body endurance exercise requiring an all-round lean body build and strength. Although many of the prediction studies use junior rowers, elite rowers are generally found to be tall and lean with long arm leavers for the production of greater force on the water.

2.6 Paediatrics

This section provides an overview of paediatrics and the impact it has on the development of young people. Aerobic and anaerobic factors are reviewed with attention focused on the differences between children and adolescents. Towards the end of this section, attention is focused upon several studies which have used the MSFT as a way of assessing cardiorespiratory fitness and how performance correlates to BMI.

2.6.1 Maturation of the developing child

Maturation is the continual development of growth in a child from birth to around 20 years old. During this 20 year period, changes occur at different stages and rates called non-linear biological maturation (Ford et al 2011) and can be observed as differences in body shape and structure. The most rapid of these stages is between birth and early childhood (0-6 years old). After, a constant growth is seen during middle childhood (7-11 years old) with rapid growth thereafter called the adolescent spurt (11-16 years old). The adolescent spurt slows down until completion of adolescent (16-20 years old) (Balyi & Hamilton, 2004). Four keys stages have been described during puberty as; Anatomical, neurological, muscular and metabolic changes (Ford et al. 2011). With these major changes in growth, athletic performance is adjusted at each individual stage.

2.6.2 VO_{2max} in young people

VO_{2max} linearly increase every year in young people, with an average rise of 225ml/min every year (Rowland, 1990). This average increase is due to growth in dimensions of the oxygen delivery system where heart and lungs see an increase in weight by up to 42% and 58% respectively in 8-12 year olds. In boys VO_{2max} is stable at 16 years old however, a decrease is seen due to the growth of muscle and oxygen delivery system. A greater decrease is seen in girls after the age of 16. A decrease from 50 $ml \cdot kg^{-1} \cdot min^{-1}$ to around 40 $ml \cdot kg^{-1} \cdot min^{-1}$ can be observed, thought to be due to a greater build-up of adipose tissue and other cultural age factors. This observation can be seen in Mota et al (2002) where they observed a variation in VO_{2max} and % body fat highlighting the importance of body composition in aerobic fitness. Mota et al (2002) also observed VO_{2max} to increase in males due to growth factor however, females only increase proportionally to body weight up until a point in late puberty.

Studies have been conducted to define the optimal cut off point for low aerobic fitness in young people. The European youth heart study (Adegboye et al, 2010) found cut of points in 4,500 school children aged 9 and 15 years olds. They suggest values in girls of 37.4 $ml \cdot kg^{-1} \cdot min^{-1}$ for 9 year old and 33 $ml \cdot kg^{-1} \cdot min^{-1}$ for 15 year olds, and in boys 43.6 $ml \cdot kg^{-1} \cdot min^{-1}$ in 9 year olds and 45 $ml \cdot kg^{-1} \cdot min^{-1}$ in 15 year olds.

2.6.3 Respiratory factors

Before puberty, little changed in FEV_1, Vital capacity (VC) or aerobic capacity is seen in both sexes (Bale, 1992) other than a little general increase with age but this is relative to body weight (Rowland, 1990). Between the years of 8-12 an increase in forced vital capacity can be seen from 1890ml to up to 2800ml (48% increase) (Rowland, 1990) causing maximal aerobic capacity to increase. At 11 years of age, maximal aerobic capacity is around 2.0 L/min and 1.85 L/min in boys and girls respectively. Girls tend to level off however, boys continue to increase their aerobic capacity so that they are around 15-50% higher.

Respiratory exchange ratio values have been observed to be lower in girls aged 8-10 than in women aged 20-32 during 30 minutes of running at 70% VO_{2max} (Martinez et al. 1992). The authors believed that this decrease in girls is due to substrate metabolism and the fact the girls rely on fat utilization more than women (Martinez et al. 1992). But, another study (Rowland et al. 1995) observed a change in RER during steady state cycling for 40 minutes at 63% VO_{2max}. Also no change in RER has been observed in boys and men while cycling at 60% VO_{2max} for 1 hour (Macek et al. 1976) therefore, this leads to conflicting views amongst the literature as to whether RER is effected by age.

2.6.4 Cardiovascular factors

The heart increase in size during growth, increasing cardiac output (Q). In children with small hearts, heart rate is higher ranging from 195-220 Bpm as stroke volume is lower due to the decrease in size (Bale, 1992). With this lower stroke volume, a-vO_2 diff is bigger in children. Once the heart has fully grown, a females heart is on average 85% the size of a male heart therefore, stroke volume and Q are similarly reduced in females than males.

Blood pressure during growth steadily rises in both systolic and diastolic functions. Around the age of 12 years old systolic blood pressure is around 160 mmHg and increases to around 200 mmHg at 17. We see no difference in diastolic blood pressure which is maintained at 70-80mmHg. Males finish with a higher systolic blood pressure due to their larger heart and greater stroke volume (Bale, 1992).

Haemoglobin levels appear to be lower in girls, explaining the decrease in aerobic capacity as there is less haemoglobin to transport the oxygen to the working muscles. Girls have around 12-16g/100ml of blood whereas boys appear to have 14-18g/100ml of blood, contributing to the a-vO_2 difference (Bale, 1992).

2.6.5 Anaerobic threshold and metabolism

Anaerobic power is related to the development of muscle mass in young people. Lean body mass increases during growth however, Rowland (1990) suggests other factors including neuromuscular activation, changes in enzyme activity and improvements in motor control are all related to anaerobic power. During growth we see an increase in power output of around 6 w/kg (7-8 year olds), 8.6 w/kg (11-12 year olds) and 10.2 w/kg (14-15 year olds) in boys. This steady increase during growth is correlated to sprint mean velocity of around 3.64m/sec (6 year olds), 5.94m/sec (12 year olds) in boys and 7.76m/sec (20 year olds) in males (Boisseau & Delamoche (2000).

2.6.6 Assessment of aerobic fitness in young people

The MSFT is regularly used to assess children's cardiorespiratory fitness levels in schools. MSFT results in young people have been observed by Mota et al (2002) where they suggested maturity status resulted in around 55% of variation in boys and 40% of variation in girls during test scores. This suggested a linear improvement in MSFT results until growth cesses at the end of puberty. A recent study has used the MSFT as a measure of cardio respiratory fitness against BMI (Aires et al, 2010). The purpose of their study was to analyse the relation between BMI and the MSFT as well as levels of physical activity using accelerometry. BMI was inversely and significantly correlated to the MSFT however, changes in physical activity levels did not influence any changes in BMI therefore, no association was found. Aires et al (2010) study showed that the MSFT is a strong measure if cardio respiratory fitness in 111 children aged 11-18 years old but BMI should be used with caution. BMI is a very popular way to assess obesity however, fails to take into account fat and fat-free mass. BMI also changes over time whereas cardiorespiratory fitness levels may decrease (Stratton et al, 2007). Stratton et al (2007) observed these findings in a cross-sectional, longitudinal study from 1998-2003 in English school young people aged 9-11. MSFT scores decreased, even among lean young people therefore, Stratton and colleges concluded that an increase in physical activity is required to increase physical activity levels in all, not just obese and overweight young people.

The MSFT in an indirect measure of VO_{2max} in children however, methods have been developed for the direct measurement of aerobic fitness. Assessment can be complete while running, cycling or rowing. Rowing provides a whole body work out, activating nearly every muscle in the body and also uses both legs simultaneously instead of alternating during running and cycling (Secher, 1993). Several studies (Wilson & Chisholm, 1993; Gibson et al, 2000) have shown that rowing ergometry is an effective method of measuring aerobic fitness in boys (aged 9-12 years old) however, to the authors knowledge no study has shown this in girls.

2.6.7 Strength in young people

Muscle strength peaks at 13-16 years old for boys and 11-15 years old for girls whereas speed increases earlier at 5-7 years old and 12-14 years old in boys and 5-7 years old in girls (Viru et al. 1999). This strength can be assessed using several different field test based methods including a hand grip dynamometer, vertical jump test and the sit-and-reach test. Recently, Milliken et al (2008) identified several useful tools to assess muscular fitness in young people which included BMI, hand grip strength, long jump and vertical jump.

Hand grip strength has become a popular way of assessing musculoskeletal strength in young people. Several studies (Espana-Romero et al, 2008) have shown the reliability of the test with little difference being shown between dynamometers (Espana-Romero et al, 2010). Hang grip strength has been shown to increase with age approximately parallel for both boys and girls with boys showing to be significantly stronger in 530 Swedish young people (Hager-Ross & Rosblad, 2002). There are however, a few errors in assessing hand grip strength. The dynamometer should be adjusted to suit each child's hand span to ensure the maximum grip strength is achieved. Ruiz et al (2006) and Espana-Romero et al (2008) both found that there is an optimal grip span for each child therefore, the dynamometer should be adjusted accordingly every time hand grip span is measured. Researchers also have to be careful in assessing right and left hand strength. There is also a lack of norms for grip strength in young people making it hard to judge strong or weak hand strength (Hager-Ross & Rosblad, 2002). A number of different dynamometers also exist and have different methods of evaluating grip strength. Types include Jamar, DynEx and TKK dynamometers and all have been used in studies. The most reliably way of measuring hand grip strength is with the elbow extended with the TKK dynamometers providing the most valid and reliable results (Espana-Romero et al, 2010)

In summary, maturation and growth in young people sees endurance and strength increase but, at different times during maturation, dependant on age and gender. Girls tend to develop earlier than boys therefore, sports performance can be seen to be more girl dominant. Once boys reach girls, most overtake girls in growth and develop greater strength.

2.7 Proposed solution

The MSFT is a well-documented popular way to predict VO_{2max} however, the validity of the test is still questioned in some population groups. Therefore, the following hypothesis proposes that:

1. A linear relationship between work rate and VO_2 in a running VO_{2max} and a rowing based incremental VO_{2max} protocol will be observed. Nomograms developed from the results will be able to accurately predict VO_{2max} in the regular gym user.
2. The validity of the MSFT will be questioned using active young people (8-12 years) and tested against other fitness measuring including speed and strength. It was further hypothesized that VO_{2max} in girls would be higher at earlier ages than boys.

Chapter III. General methodology

The following section provides, in detail, all materials and procedures used during both study A (Rowing MSFT, Chapter IV) and study B (Children's MSFT, Chapter V). More detailed information is provided in the specific study chapters.

3.1 Health and safety

Approval by the University of Bedfordshire ethics committee was given (*see Appendix I*) for the collection of data for both projects. Apparatus used for the collection of respiratory gases in study A was the Cortex Metalyzer 3B (Cranleigh, UK) included mouthpieces and turbines. These were cleaned using a dilute 1 % virkon solution prior and post use. Heart rate monitors (Polar) were worn at all times during study A and were washed in soapy water post exercise before further use.

3.2. Standardisation and familiarisation procedures

3.2.1 Participants

In study A, all participants were students of staff from the University of Bedfordshire. Prior to all experiments participants were made aware of what exercise they would be required to do and received a subject information sheet (*See Appendix IV & V*). A PARQ (*See appendix VI*), informed consent (*See appendix IV &V*) and blood sampling questionnaire (*See appendix VII*) were also given and signed before any exercise to ensure the subject was in good health. This was also checked and signed by the experimenter before any exercise commenced. All sheets were kept by the experiment for the remainder of the three experimental trials. Participants were free to withdraw from the study at any time.

In study B, all participants were active young children between the ages of 8-12 years olds from Bedford & County Athletics club. All assisting coaches had full up to date CRB checks and England Athletics coaching licences of level 1 or above. A subject information sheet (*See appendix IV & V*) was given to all parents and a signed consent form was completed before any testing was conducted. Every participant was given a number, with times and scores being kept confidential for the remainder of the testing procedure.

3.2.2 Pre experimentation diet and exercise standardisation

Study A

Prior to laboratory testing, subjects were asked to refrain from ingesting alcohol and caffeine for 48 hours and exercise 24 hours before. The consumption of food was refrained for at least two hours before exercise and subject bookings were attempted at around the same time off day to minimise the effect of circadian variation (Winget et al, 1985). All rowing tests were performed on a concept II (Model D, Cranlea, Nottingham, UK) rowing ergometer (Figure 3.1 & 3.2).

Figure 3.1. Concept II rowing ergometer in the University of Bedfordshire laboratories.

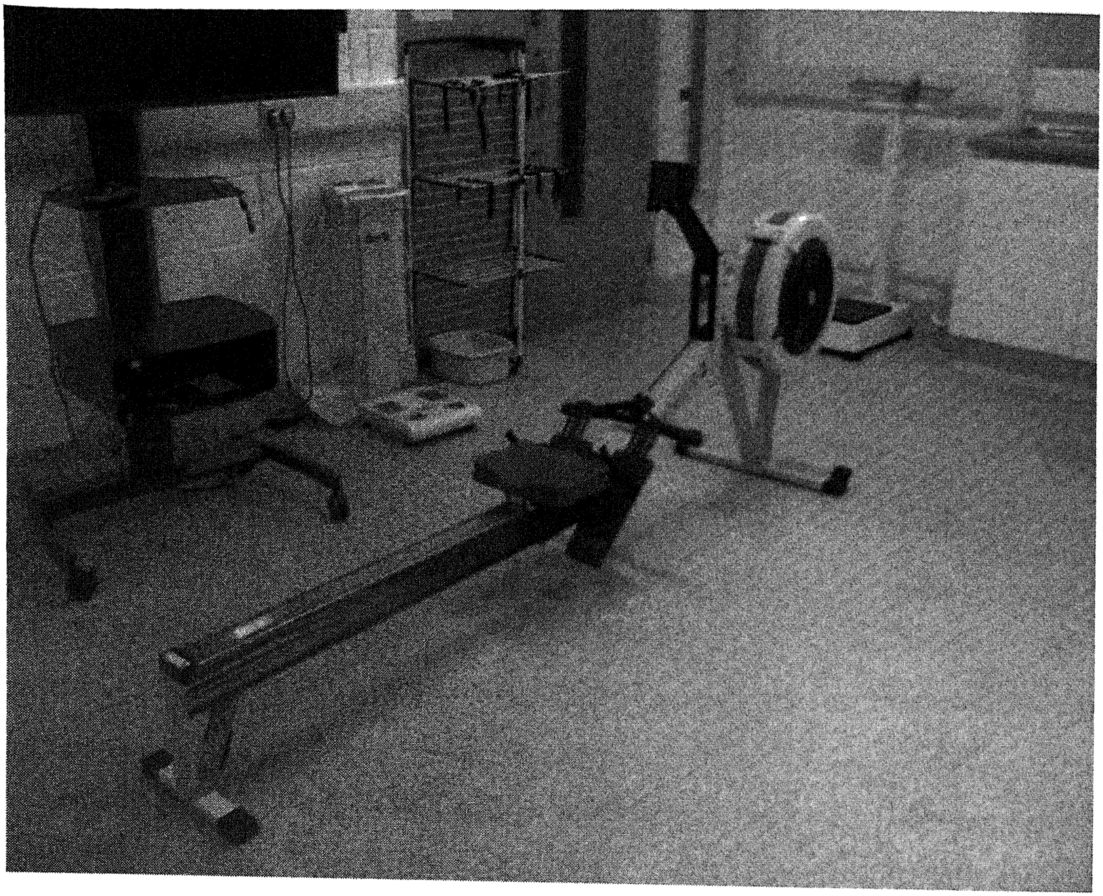
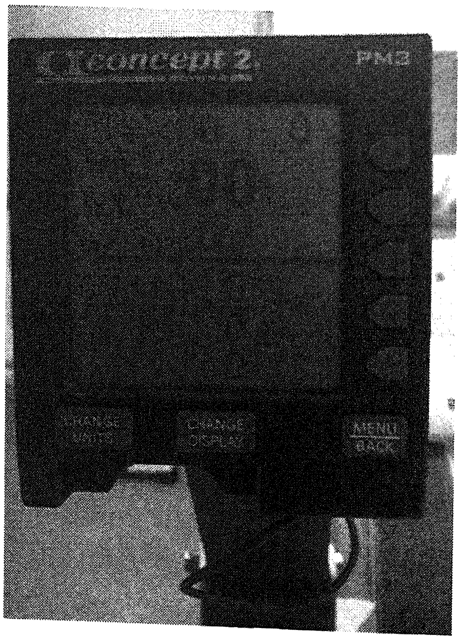


Figure 3.2. Screen displayed for participant's during the rowing tests on the concept II rowing ergometer.



Study B

Prior to testing, young people would have been at school, either on a Tuesday or Thursday and arrived at the Bedfordshire International Athletics Stadium for 17:30. A 10 minute slow jogging warm up was completed as well as a series of specific athletic drills.

3.3 Experimental designs

Study A

Subjects were required to visit the laboratory three times for both the rowing and running experiments. These visits were conducted in a counterbalanced order therefore, subjects acted as their own controls for the experiments. Visits included a maximal oxygen uptake test (VO_{2max} test), incremental rowing exercise test (IRT) and a 2,000m performance time trial on a concept II rowing ergometer.

Study B

All testing was complete within one hour and a half and had a set order which was repeated for all data collection sessions. Anthropometric data was first collected before any performance data. Performance data was collected with sprints (10 and 40m) then, strength dynamometer tests and finally the MSFT to finish. For more information on the order and recommendations *see section 5.5.*

3.3.1 Rowing multi-stage fitness test pilot data

Pilot testing was conducted on the design of a new rowing based multistage fitness test before a single design was taken forward. This was to ensure the correct final protocol was chosen which gave the most accurate prediction of $VO_{2max.}$ It was also used to test out the apparatus (Concept II ergometer, cortex metalyser) and practicality of a test for rowing.

It was decided early on that the new test would be correlated to a running VO_{2max} test. There are currently many versions of a rowing VO_{2max} test on ergometers in the literature including variations in time, power output (Watts), distance and stroke rate (Table 3.1). Many of these tests include power output increments however, our new test would be unable to include power output increments with only a audio signal to replicated the test. The test also has to be a continuous incremental test to exhaustion.

Table. 3.1. Publications to show seven different variations in rowing VO_{2max} testing protocols.

Author	Starting load	Increments/decrements
Mickleson & Hagerman, 1982	Stroke rate around 28-32	47.2W. 101.2W, increments of 27W till exhaustion
Hagerman et al, 1988	50W	50W every 2 minutes
Cosgrove et al, 1999	500m @ 24-28 strokes per minute	Time decrements every 5 seconds
Kennedy & Bell, 2000	100W	50W every 2 minutes
Yoshiga & Higuchi, 2003	140W males/125W males	50W males/25W females every 2minutes
Jurimae et al, 2007	40W (Resistance fixed @ 5)	20W every 1 minute
Huntsman et al, 2011	200W males/150W females	50W every 2 minutes

A standard running incremental VO_{2max} test is the gold standard for maximal oxygen consumption and will give the most accurate VO_{2max} reading. This will be used to correlate against the incremental rowing protocol (IRT).

Three ideas were taken forward for pilot testing; Distance vs time where time decreases while distance stays constant. The participant had to row quicker to keep up until they can't keep the pace. An incremental stroke rate based test where the participants stroke rate increases every minute till exhaustion and finally a load based incremental design where watts would be increased till exhaustion.

The first test conducted was a distance vs time protocol where the increments were set at 100m per stage with a time decrement at 10 seconds. During testing, start time and decremental stage time were considered for the best VO_{2max} output. The pace started at 4 min per 500m pace. Every100m a decrease by 10km/h (Table 3.2) was required.

Table. 3.2. An example of the distance Vs. time protocol data collection sheet.

500m pace (Km/h)	Distance (M)	Time (Min:Sec)	VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	HR (Bpm)
4:00	100			
3:50	100			
3:40	100			
3:30	100			

The second pilot test was the load incremental test. The test began at 40W for each participant and increased by 20W every 90 seconds (Table 3.3).

Table 3.3. An example of the stage load incremental test data collection sheet.

Time (Min:Sec)	Stage		Watts (W)	VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	HR (Bpm)
00:30	1	1	40		
1:00		2	40		
1:30		3	40		
2:00	2	1	60		
2:30		2	60		
3:00		3	60		
3:30	3	1	80		
4:00		2	80		
4:30		3	80		

The third pilot test was a design based around the work of Cosgrove et al (1999) who used stroke rate for their tests. They suggest using 24-28 strokes per minute

(S/min) with increments up to 28-32 S/min. With regards to this, stroke rate increased by 2 S/min every minute, starting a 24 S/min (Table 3.4)

Table 3.4. An example of the stroke rate based incremental protocol data collection sheet.

Time (Min/Sec)	Stroke rate (S/min)	VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	HR (Bpm)
2:00	24		
4:00	26		
6:00	28		

In summary, all there protocols successfully had an incremental increase in VO_{2max} however, several practical problems arouse. The load incremental stage test was dropped due to its similarity with a standard incremental VO_{2max} test and its difficulty with regulating power output. The distance Vs time protocol was dropped due to its difficulty in setting up with the time and pace decrements. This type of protocol would be difficult to control without visual software or a pre-programmed piece of software in the concept II rower. The stroke rate based protocol was taken on for further pilot testing. The test provides an increment which can be increased via an audio signal, similar to the running based version of the multistage fitness test. It is also an increment which can be employed with headphones in a gym based environment using an app.

Stroke rate based protocol one (PT1)

Three male subjects (21 years old; Av height 170 Cm, Av weight 63 Kg) were recruited to test the protocol. The protocol was modified from Cosgrove et al (1999) suggestions about starting stroke rate. Stroke rate began at a lower S/min of 15 per min and increased by 3 S/min, every minute (Table 3.5). A metronome was used for the first time to ensure the correct stroke rate was maintained. The bleep was positioned at the front of the rower to maintain the same place every bleep.

Table 3.5. An example of the data collection sheet for PT1.

Time (Min:Sec)	Stroke rate (S/min)	VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	Heart rate (Bpm)
0	15		
1:00	18		
2:00	21		
3:00	24		
4:00	27		
5:00	30		
6:00	33		
7:00	36		
8:00	39		
9:00	42		
10:00	45		
11:00	48		
12:00	51		

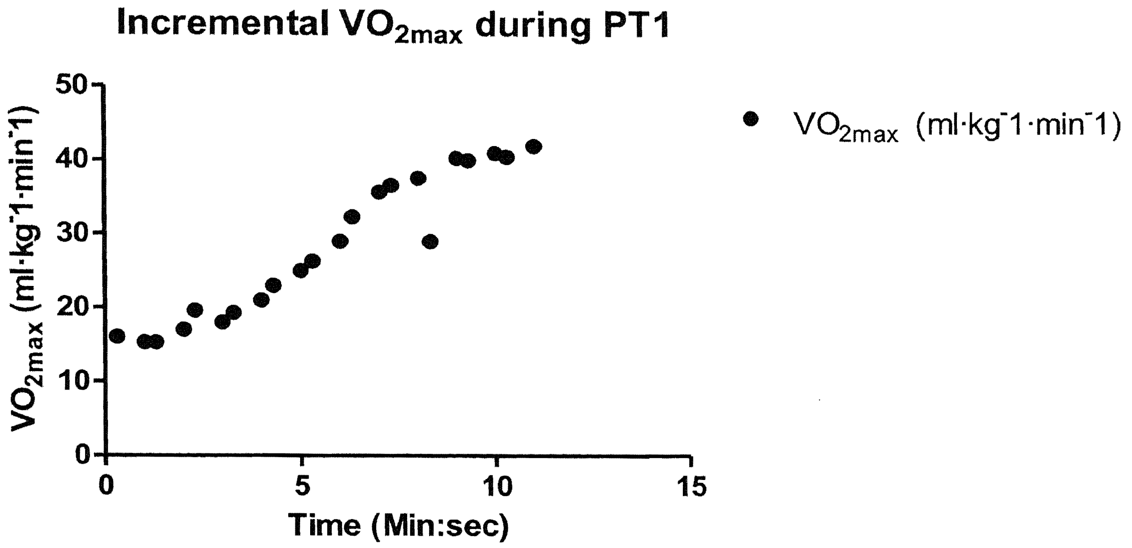


Figure 3.3. Average VO_{2max} (ml·kg^{-1}·min^{-1}) during the incremental PT1 (n = 3).

In conclusion, PT1 showed that stroke rate could be used as an incremental variable for exercise and the audio signal (metronome) successfully maintained the required stroke rate. The VO_2 however, was lower than expected in the health male subjects recruited (Figure 3.3) and subject feedback confirmed that they felt as though they were stopping due to the speed of the stroke rate rather than cardiovascular fatigue.

Stroke rate based protocol 2 (PT2)

In PT2 several modifications were made including a reduction in each stage length from 1 minute to 30 seconds and stroke rate increased by 1 S/min instead of 3 S/min. Heart rate was also monitored to see if a linear response is observed, similar to VO_2. Again 3 male subjects were used (21 years old; Av height 176 Cm, Av weight 66Kg) and asked to refrain from exercise 24 before the test.

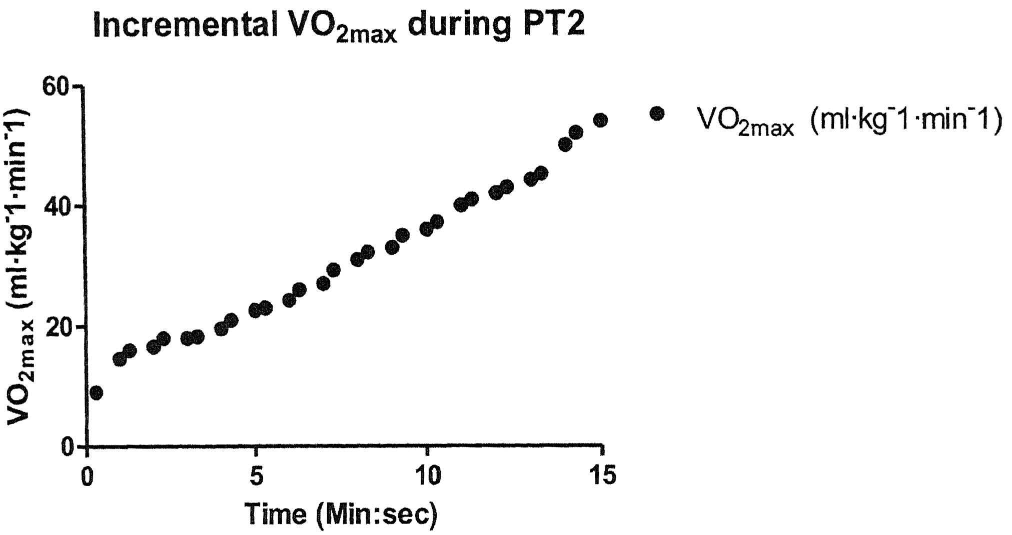


Figure 3.4. Average incremental VO_2 (ml·kg^{-1}·min^{-1}) during incremental PT2 (*n* = 3).

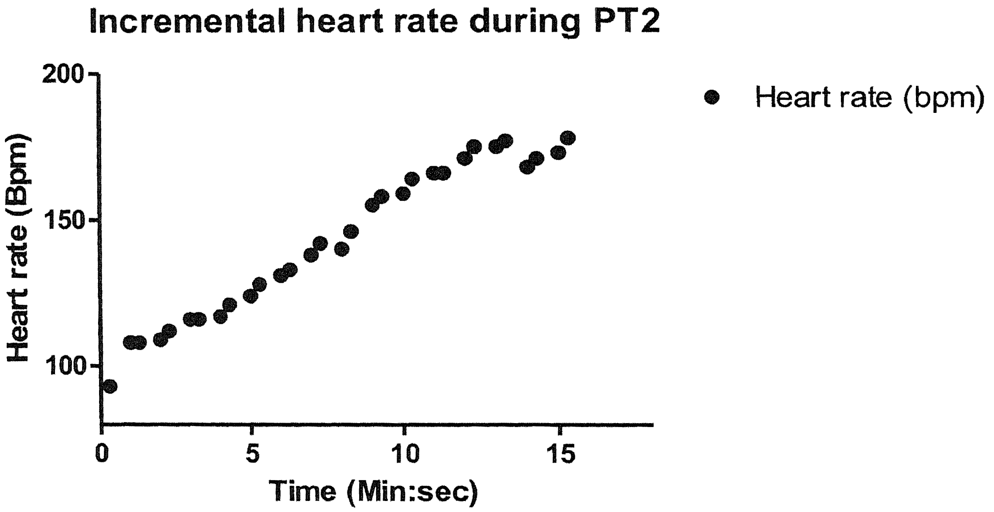


Figure 3.5. Average incremental heart rate (Bpm) during incremental PT2 (*n* = 3).

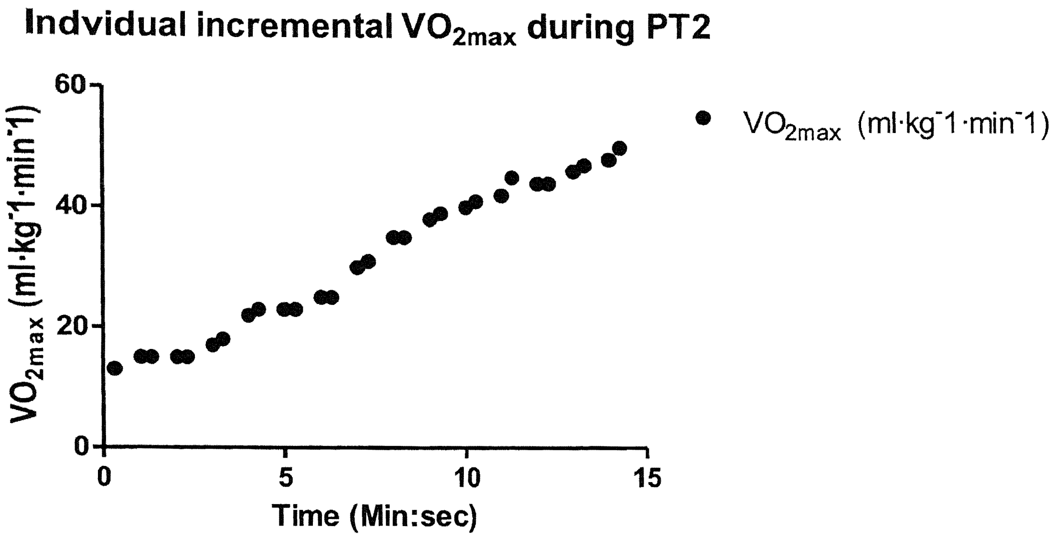


Figure 3.6. Individual average VO_2 (ml·kg^{-1}·min^{-1}) during incremental PT2 (*n* = 1).

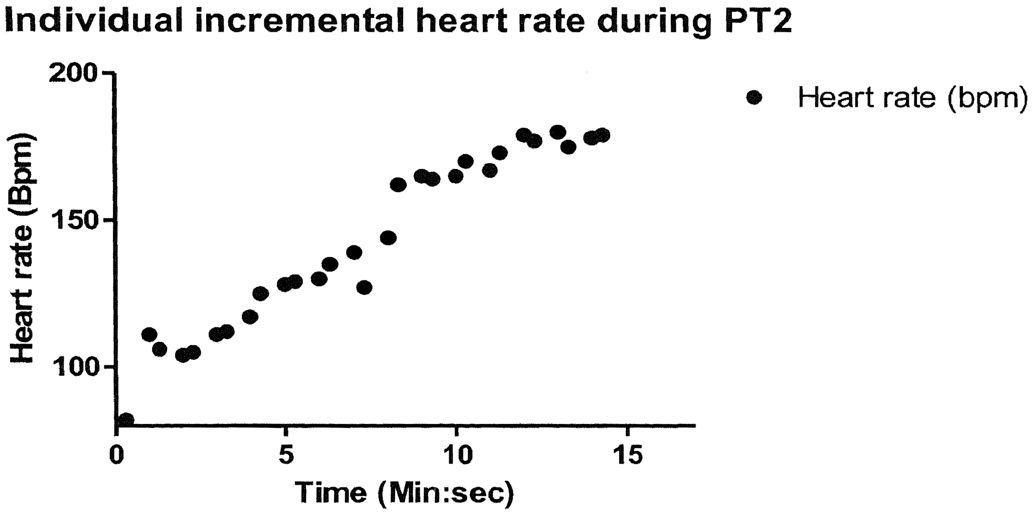


Figure 3.7 Individual average heart rate (Bpm) during incremental PT2 (*n* = 1).

In conclusion, the results of PT2, similar to PT1 showed that the protocol successfully produces an incremental exercise test using stroke rate (Figure 3.4). Participants did however, again complain about dropping out due to stroke rate and not cardiovascular fatigue. In one participant (Figure 3.7), heart rate was almost at a steady state for around 5 minutes at the start of the test until a stroke rate of 24 was required. This suggested that the first 5 minutes of the test is too easy and like PT1, 24 S/min is a good starter stroke rate. This would also reduce test time as the test took nearly 15 minutes.

Stroke rate based protocol 3 (PT3)

A new pre incremental 500m rowing phase was introduced into PT3 for participants to familiarize themselves with listening to the audio signal and regulating their stroke rate. Following the results of PT2, the pre incremental 500m phase would start at 24 and 28 S/min for females and males respectively. A 2 minute break was introduced before the start of the test, which would be the same as PT2 however, starting at individual gender specific stroke rates. RPE was observed throughout to see if participants were reaching maximal fatigue sensation. Time to exhaustion and RER were also measured.

Table 3.6. Mean ± SD for the results from PT3 (n = 5).

Participants	Gender	VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	HR_{max} (Bpm)	RPE_{max}	RER	TTE (Min:Sec)
1	M	55	168	17	1.27	15:00
2	M	46	161	16	0.97	18:00
3	M	37	176	16	1.07	20:00
4	M	52	182	20	1.00	16:00
5	F	36	172	18	1.20	13:00
Av		44.9 ± 8.5	177 ± 7.9	17.4 ± 1.6	1.10 ± 0.1	16:40

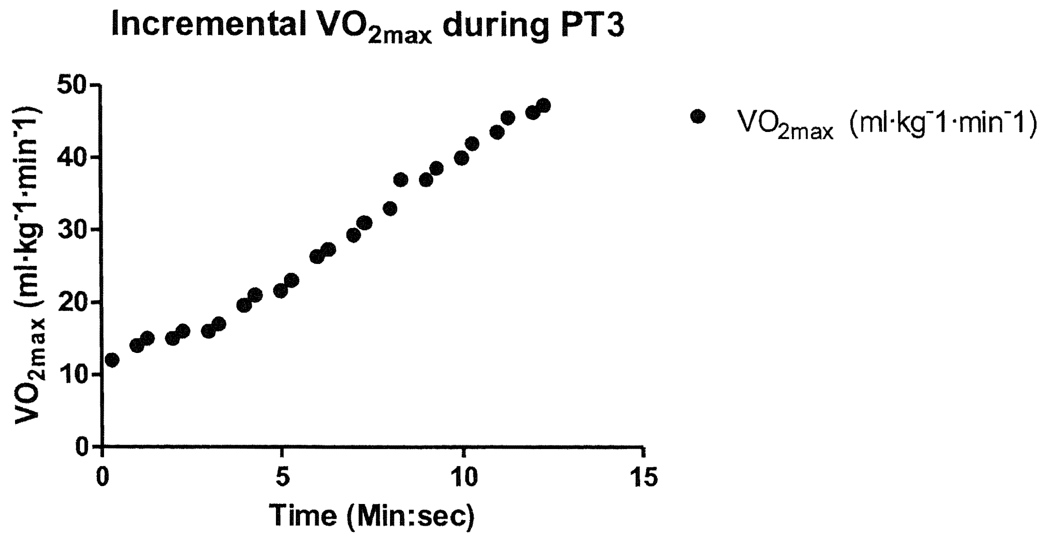


Figure 3.8 Average VO_2 (ml·kg^{-1}·min^{-1}) during incremental PT3 (*n* = 5).

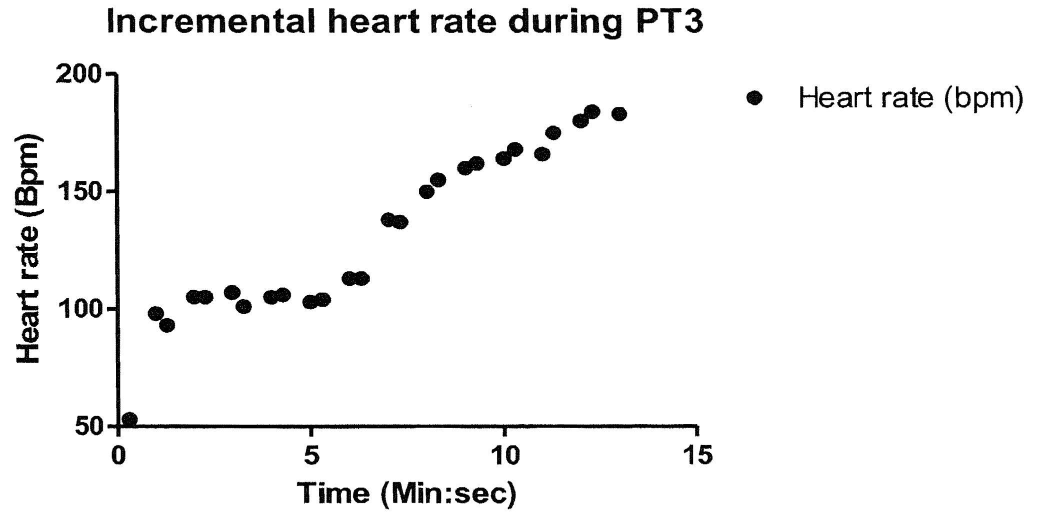


Figure 3.9. Average heart rate (Bpm) during incremental PT3 (*n* = 5).

Heart rate during PT3 (Figure 3.9) was more incremental than in PT2 suggesting that the pre incremental 500m phase warmed up and familiarized the subjects as well as setting a correct starting speed. VO_2 also had a far greater linearly increases in PT3 than PT2 with a slight drop towards the end of the test; characteristic of a VO_2 plateau. The results do however, suggest that VO_{2max} is not achieved with HR struggling to reach 220-20 Bpm, RER above 1,15 and RPE above 18 (Table 3.6) combined with a very long time to exhaustion. In response to these results, subjects one and three also did a running based VO_{2max} test. The test started at 8km/h, increasing by 1km/h every minute with a test duration time of 8-12 minutes (Yoon et al, 2007).

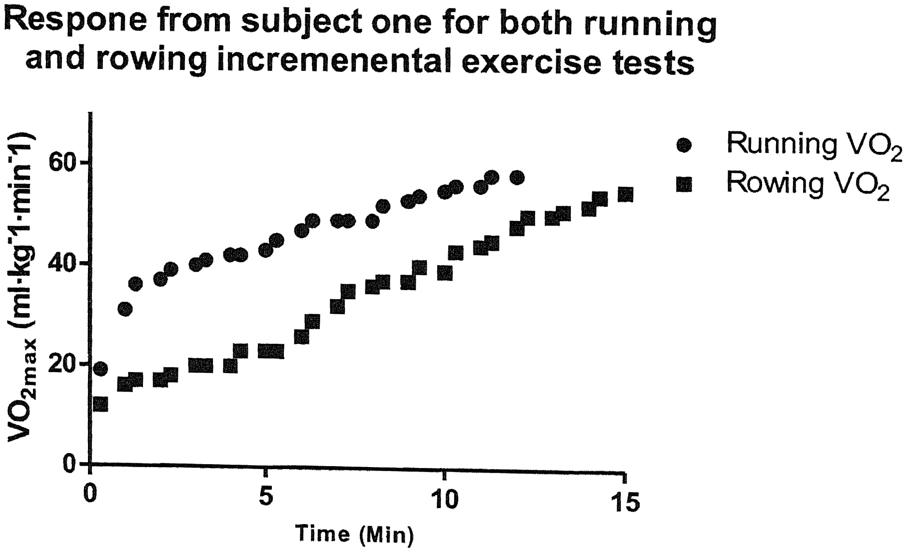


Figure 3.10. Response from subject one during running and rowing incremental exercise tests.

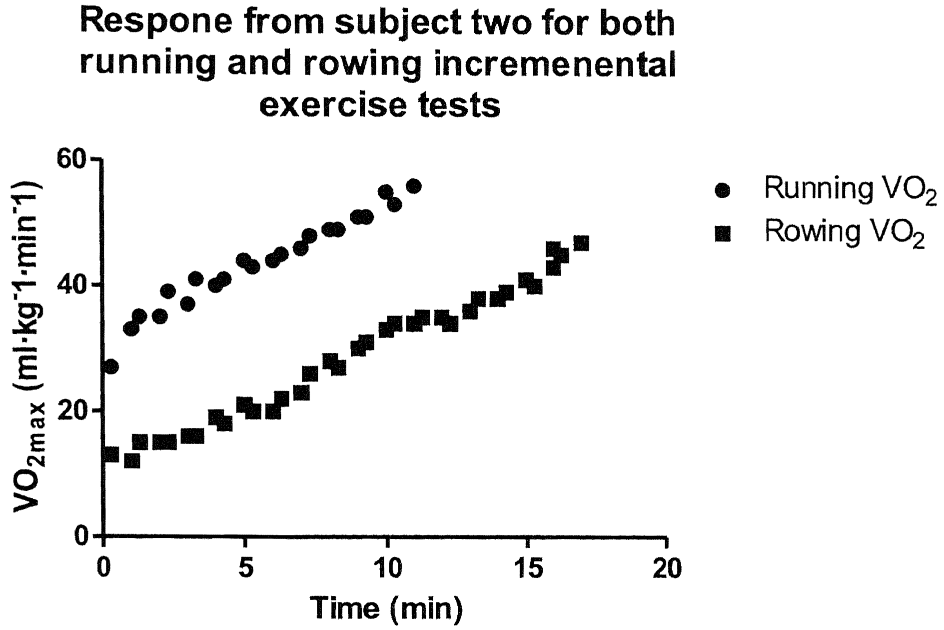


Figure 3.11. Response from subject two during running and rowing incremental exercise tests.

The two running based VO_{2max} tests (Figure 3.10 & 3.11) show running VO_2 correlated to rowing VO_2 throughout by an average 20 ml·kg^{-1}·min^{-1} higher. Running VO_{2max} finished in the desired time limit of around 8-12 minutes whereas rowing went over 12 minutes. A large gap observed in VO_2 has been suggested to be because of the athletic subjects used in this part of the pilot testing with running VO_{2max} seen at around 60 ml·kg^{-1}·min^{-1}. Subjects with lower VO_{2max} may reproduce similar results on both treadmill and ergometer tests.

In conclusion, pilot testing was conducted over a period of one month to ensure the correct protocol was taken forward for full testing. In light of PT3's results, the subject population used for full testing would be gym users with a VO_{2max} of around 30-50 ml·kg^{-1}·min^{-1}. This subject group was also chosen as it is in the gymnasia where the final Coachwise product will be marketed.

3.3.2 Rowing performance time trials

In study A, a 2,000m rowing performance time trial was completed in a counter-balanced design with the incremental rowing test (IRT) and running based VO_{2max} test. All time trials were completed on a Concept II rowing ergometer. Blood was taken before and after each time trial for B[La] analysis and a 2 minute warm-up was given before the 2,000m time trial to each participant for familiarization and warm-up procedure.

3.3.3 Experimental procedures

Study A

On arrival, all paperwork was complete before the measurement of both height (Cm) and weight (Kg). Height was measured using a stadiometer (Holtain) and weight using scales (Tanitia, BWB0800, Allied Weighting) (Figure 3.12)

Figure 3.12. Scales used for measuring weight (Kg) and stadiometer used for measuring height (Cm)

Study B

On arrival to the athletics track, participants completed a 2 lap warm-up, around the outside of the track on grass. They were then put through standard running drills (i.e High knee's, heel flicks etc...). All participants were used to completing the warm up on a regular basis before the start off full training. Warm-up and drills lasted for around 20 minutes before data collection began.

Anthropometric data was first collected before any performance data collection began including height (Cm) using the stadomiter (Harpenden, Cranlea) and tanitia scales (BC41MA Segmental body, Cranlea) for all other measures including weight (Kg), BMI, Body fat (5), free fat mass (Kg) and total body water (Kg). Participants first completed the 10 and 40m sprints on three separate occasions with their best scores being recorded. Light gates (Brower test centre systems, Cranlea) were place between one athletics lane on the indoor sprints straight at 10 and 40m intervals. Strength testing including hand grip and pull dynamometer tests (Takei A5402, Takei A5401). Participants sat on a bench in between each activity to ensure the best recovery. Each participant went one at a time and everyone provided encouragement for each other. Finally, the MSFT was conducted as a whole group. MSFT was left till last as it was a full test of aerobic endurance and requires a long recovery time. A cool down of 2 very slow laps the opposite way around the athletics track was complete followed by 15 minutes of light stretching.

3.4. Measures and apparatus

Study A

(See section 4.2.2)

Study B

(See section 5.2)

3.4.1 Measuring maximal oxygen uptake

Maximal oxygen uptake (VO_{2max}) was measured using a cortex Metalyzer 3B (Cranleigh, UK). VO_{2max} stands for V, volume and O_2, oxygen at the body's maximum. It can be calculated using the flick equation (*See section 2.2.1*).

The respiratory quotient (RQ) is measured using the respiratory exchange ratio (RER), expressed as VCO_2/VO_2. When the ratio is measured as 1.00, carbohydrates are exclusively used, at 0.82 proteins and 0.70 fats. RER becomes a good indirect, non-invasive method for the fat and carbohydrate contributions during exercise.

3.4.2 Subjective measurements

Study A

Subjects were asked for their rate of perceived exertion (RPE) (Table 3.7) during the treadmill based VO_{2max} test and the IRT. This was to ensure that every participant had reached their maximum. The scale ranges from 6 (very very light) to 20 (very very hard) (Borg, 1972; table 3.7).

Table 3.7. 6-20 Rate of perceived exertion scale (Borg, 1972).

6	
7	Very Very Light
8	
9	Very Light
10	
11	Fairly Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Very Very Hard
20	

3.4.3 Determination of blood lactate concentration

Study A

Blood lactate (B[la]) was obtained via a figure prick blood sample using an automated lancet (Analox, LM5). The automated lancet was calibrated every morning before any samples were taken. An alcohol wipe was used to clean the site before the figure was stabbed using a lancet. The first drops of blood were wiped with a tissue due to fluid before a capillary tube was using to collect the blood. The blood was then inserted into the automated lancet where a reaction took place –

$$\text{L - Lactate} + O_2 \xrightarrow{\text{L – Lactate Oxidase}} H_2O_2 + \text{Pyruvate} \tag{3.1}$$

3.5 Statistical analysis

Statistical analysis was performed using statistical packages for social science (SPSS version 19; Graph Pad Prism 5). Students paired t-tests were used for comparison between final values in study A between male and female/ rowing and running VO_{2max}, heart rate, RER, B[la], RPE, performance times and exercise duration. A pearson's product moment correlation coefficient was used for relationships in study A between VO_2, heart rate and 2,000m rowing performance. In study B, the MSFT was correlated to 10m, 40m, hand grip dynamometer and pull dynamometer performance scores as well as anthropometric data.

Correlations were used for the validity of the novel incremental rowing test in study A and MSFT in young people in study B. For example, 2,000m rowing performance was correlated to VO_{2max} performance to ensure concurrent validity in study A and MSFT was correlated to performance measurements for predictive validity (Currell & Jeukendrup, 2008) in study B. In both studies a linear regression analysis was used to calculate the predicted VO_{2max}:

$$Y = a + bX \tag{3.2}$$

Data was presented as means ± SD to observe the differences in means and therefore, showing the effect size. Standard error of measurement (SEE) was shown in study A to present the amount of error expected in predicating VO_{2max}. Statistical significance was accepted at the $P < 0.05$ level. Other statistical analyses used during pilot testing are described in the appropriate sections (*See sections 4.2.4 & 5.2.1*).

Chapter IV. The use of an indoor rowing test for the prediction of maximal oxygen uptake (Study A)

4.1 Introduction

Rowing has become a very popular form of physical activity as well as a competitive sport. Most gymnasia in the UK have rowing ergometers to provide a whole body workout requiring the ability to sustain a high aerobic capacity. The 2,000-m row is the most common competitive distance lasting around 6-7 minutes in Olympic rowers therefore, the ability to maintain a high VO_2 is required. Maximal oxygen uptake can reach levels of up to 65-70 $ml \cdot min \cdot min^{-1}$ (Steinacker, 1993) in elite rowers.

An incremental maximal oxygen uptake test (VO_{2max} test) provides the 'gold standard' protocol for the assessment of an individual's cardiorespiratory fitness. VO_{2max} has been found to be a very strong predicator of 2000-m rowing performance (Ingham et al, 2002; Cosgrove et al, 1999). There appears to be no set protocol in the literature for a rowing ergometer VO_{2max} test but most share a stepwise based protocol design. Several attempts have been made to develop rowing-specific tests which accurately predict VO_{2max}. Lakomy & Lakomy (1993) estimated VO_{2max} from sub maximal exercise using predicted HR_{max}, 220 beats min^{-1}-age with mean error of less than 5% being observed. In addition, more recently Huntsmen et al. (2011), accurately predicted VO_{2max} using heart rate in men ($r = 0.55$) however, inadequately in women ($r = 0.05$) during an on water rowing test. Both these studies suggest than HR_{max} can be accurately used to predict VO_{2max} in rowing.

The multistage fitness test (MSFT) (Ramsbottom et al, 1988) is an incremental test which predicts VO_{2max} using a nomogram. The test can be performed outdoors on large subject numbers without the requirement of a heart rate monitor or oxygen consumption equipment. The MSFT is incrementally progressive test where the participant increases their speed every stage, similar to a laboratory based test. Stroke rate (S/min) provides a variable which can be increased incrementally during rowing exercise and is calculated by the amount of stokes achieved every minute (Soper & Hume, 2004). During a race, stroke rate averages around 30-36 S/min with a peak of 34-38 S/min toward the end of a race (Steinacker, 1993).

The purpose of this study was to develop an indoor MSFT which can be used on a rowing ergometer, accurately predicting VO_{2max} in recreationally fit individuals. It was hypothesis that there would be an incremental relationship between VO_2 and work rate and between the incremental rowing test (IRT) and treadmill based VO_{2max} test. A 2,000m rowing test was included to ensure that the predicted validity of performance times were related to predicted VO_{2max}.

4.2 Experimental designs

To develop an incremental rowing test several different variables were considered and pilot tested (*See section 3.3.1*) before a final protocol was selected. Variables to adjust which were considered included distance (Meters), power output (Watts) and stroke rate (SR). A distance Vs. time protocol was not used as it was thought that the test would run for too long. Power output was not used as this variable is very hard to monitor with only an audio signal. SR was considered to be the best option for an incremental rowing test. Pilot testing using SR was employed to find a test that would last around 8-12 minutes (Yoon et al, 2007) and produce an accurate prediction of VO_{2max}. (For more detailed information on the pilot testing see *section 3.3.1*)

4.2.1 Subjects

Gym users (*n* 41) who exercised for around 3-5 hours a week (mean ± SD; age 21 ± 5.3, height 175.4 Cm ± 8.1,body mass 71.4 Kg ± 12.6) participated in this study. All participants were given written consent forms which were approved by the University of Bedfordshire ethics committee (*See Appendix I*).

4.2.2 Methods

Testing was carried out in the University of Bedfordshire's laboratory where the conditions were kept the same (21°c). Participants were required to visit the laboratory three times to complete a treadmill running VO_{2max} test (Woodway, PPS55 med-I, Cranlea), a new incremental rowing test (IRT) and a 2,000m row in a counter-balanced design. Rowing was performed on a Concept II ergometer (Model D, Cranlea, Nottingham, UK) with an audio signal (Seiko, DM70, Cranlea) dictating stroke rate.

Blood lactate (B[la]) was removed using an automated lancet (Hemocue, Angelhom, Sweden) and analysed (Analoz, LM5). Expired gas samples were analysed using a metabolic measurement cart (Cortex Metalyzer 3B, Cranleigh, UK) and calibrated according to manufacturer specifications prior to each test.

4.2.3. IRT protocol

The IRT began with a 500 m bout at a stroke rate at 24 S/min for females and 28 S/min for males to act as a warm up. A 1 minute rest period was given before the start of the IRT. The IRT began with participants rowing at 28 S/min for females and 30 S/min for males, and stroke rate increased by 1, every minute until exhaustion, or the desired stroke rate could not be maintained. Resistance was set at 10 for both genders throughout the IRT.

4.2.4 Statistical analyses

A student's paired sample t-test was used to compare the male/female and running/rowing differences in VO_{2max}, Heart rate, Respiratory exchange ratio (RER), rate of perceived exertion (RPE), minute ventilation (VE) and B[la]. A Pearson-product moment correlation calculated the measure to assess the relationship between each test and a regression analysis ($Y = a(x) + b$) was used for the nomogram. All data was analysed using a standard statistical software package (SPSS Version 19, Chicago, Illinois, USA) and statistical significance was accepted at the level of $P < 0.05$ value. Graphs were all created using Graph Pad Prism 5.

4.3 Results

4.3.1 VO_{2max} and VE_{max} values. VO_{2max} values were significantly higher during treadmill running (44.7 ± 6.5 ml·kg^{-1}·min^{-1}) than the IRT (42.2 ± 7.3 ml·kg^{-1}·min^{-1}; $P < 0.05$). Higher max values were observed in males during treadmill running than IRT respectively (47.7 ± 4.8 mL·kg^{-1}·min^{-1} vs. 44.7 ± 6.1 mL·kg^{-1}·min^{-1}; $P < 0.05$) however, no significant difference was observed in females (39.6 ± 5.8 ml·kg^{-1}·min^{-1} vs. 37.7 ± 7.4 ml·kg^{-1}·min^{-1}; $P > 0.05$). VE_{max} was significantly higher during treadmill running (117.46 ± 25.01 l/min) than the IRT (103.41 ± 26.06 l/min; $P < 0.05$).

Table 4.1. Mean ± SD for VO_{2max} measured in Running and IRT.

	Males (*n* 41)	Females (*n* 16)	Whole group (*n* 41)
VO_{2max}	47.7 ± 4.8*	39.6 ± 5.8	44.7 ± 6.5*
IRT	44.7 ± 6.1	37.7 ± 7.4	42.2 ± 7.3

* Indicates a significant difference in VO_{2max} ($P < 0.05$)

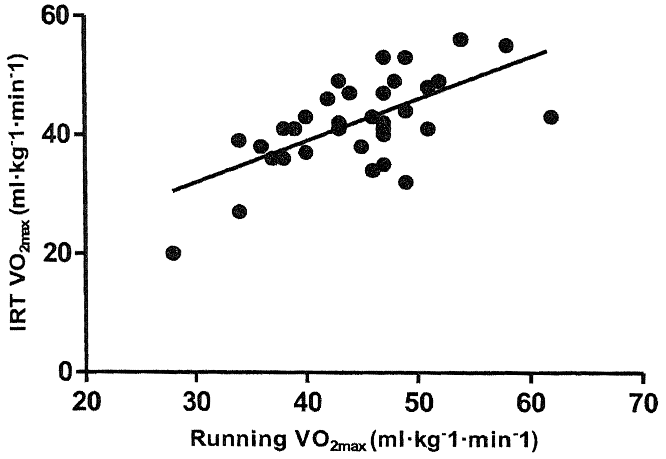


Figure 4.1. Relationship between Running and Rowing VO_{2max} values.

.3.2 Heart rate and RER. Maximum heart rate was significantly higher during the unning test (192 ± 9 Bpm) compared to the IRT (184 ± 10 Bpm; $P < 0.05$). No ignificant difference was observed in RER between running VO_{2max} and IRT espectively (1.14 ± 0.06 vs. 1.15 ± 0.09; $P > 0.05$).

4.3.3 Blood lactate and perceptual measures. No significant difference was observed in B[la] between running VO_{2max} and IRT respectively for both males (6.0 ± 1.7 vs. 5.9 ± 1.8; $P > 0.05$) and females (4.8 ± 1.8 vs. 4.9 ± 1.6; $P > 0.05$). B[la] was significantly different between IRT and 2,000m row respectively in males (5.9 ± 1.8 vs. 7.7 ± 1.7; $P < 0.05$) but not in females (4.9 ± 1.6 vs. 5.4 ± 1.9; $P > 0.05$). Final RPE scores were not significantly different between running VO_{2max} and IRT respectively (18.8 ± 1.1 vs. 18.6 ± 1.5; $P > 0.05$; Table 4.3).

Table 4.2. Mean ± SD for B[la] measurements at the start and end of each running VO_{2max} test, IRT and 2,000m row.

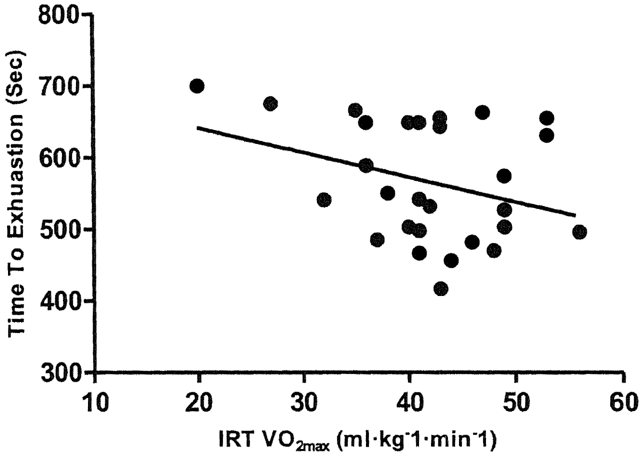
		Males (*n* 25)	Females (*n* 16)	Whole group (*n* 41)
Pre	VO_{2max}	0.8 ± 0.3	1.1 ± 0.2	0.9 ± 0.3
	IRT	1.0 ± 0.5	1.1 ± 0.5	1.0 ± 0.5
	2,000m row	0.8 ± 0.3	1.0 ± 0.3	0.9 ± 0.3
Post	VO_{2max}	6.0 ± 1.7	4.8 ± 1.8	5.6 ± 1.8
	IRT	5.9 ± 1.8	4.9 ± 1.6	5.6 ± 1.8
	2,000m row	7.7 ± 1.7*	5.4 ± 1.9	6.9 ± 2.1*

* Indicates a significant difference in B[la] ($P < 0.05$)

Table 4.3. Mean ± SD for the rate of perceived exertion (RPE) from running VO_{2max} and IRT.

	RPE (n=41)
VO_{2max}	18.8 ± 1.1
IRT	18.6 ± 1.5

Figure 4.2. Relationship between 2,000m performance time (Sec) and IRT $\mathrm{VO_{2max}}$ ($\mathrm{ml\cdot kg^{-1}\cdot min^{-1}}$).



4.3.4 Correlations. $\mathrm{VO_{2max}}$ was significantly related to treadmill running and IRT (r = 0.68, SEE=4.7; $P < 0.01$; Fig 4.3). A stronger correlation was observed in gender specific groups with females (r = 0.78, SEE 3.7; $P < 0.05$) than males (r = 0.39, SEE 4.5; $P > 0.01$). Maximum heart rate was significantly correlated between treadmill running and IRT (r = 0.76, SEE 5.8; $P < 0.01$). There was no significant difference between 2,000m rowing performance and IRT ($r^2 = 0.1065$; $P > 0.05$).

Figure 4.3. Correlation in $\mathrm{VO_{2max}}$ ($\mathrm{ml\cdot kg^{-1}\cdot min^{-1}}$) between Running and the IRT in all participants (n 41).

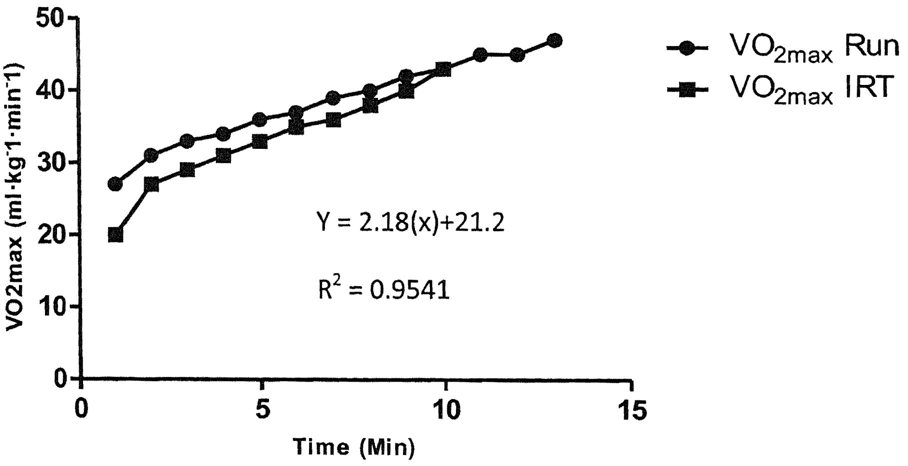


Figure 4.4. Correlation in VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) between Running and the IRT in females (n = 16).

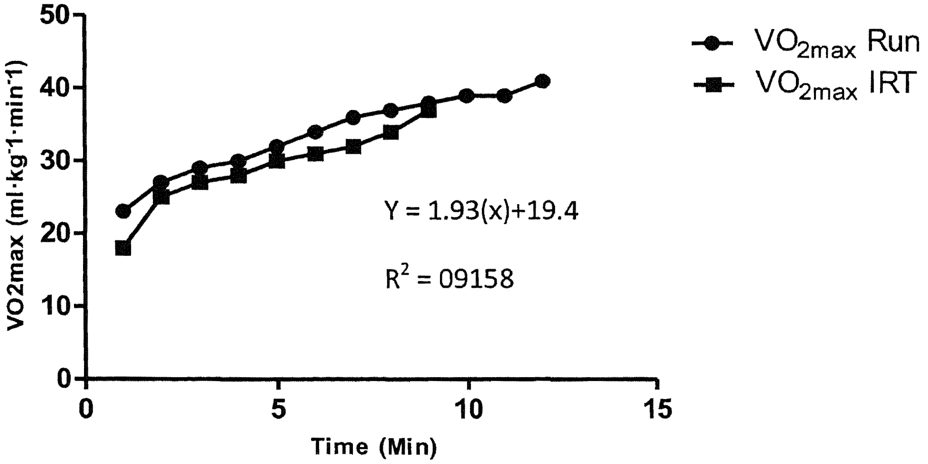


Figure 4.5. Correlation in VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$) between Running and IRT in males (n = 26).

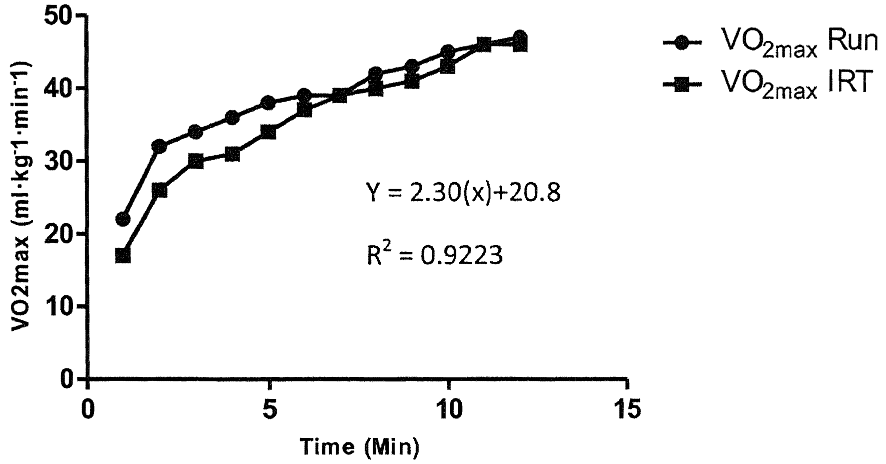


Table 4.4. A nomogram for the prediction of VO_{2max} in males (n = 26).

Time (Min : Sec)	Predicted VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	Time (Min : Sec)	Predicted VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)
01:00	23.1	07:00	36.9
02:00	26.9	08:00	39.2
03:00	27.7	09:00	41.5
04:00	30	10:00	43.8
05:00	32.3	11:00	46.1
06:00	34.6	12:00	48.4

Table 4.5. A nomogram for the prediction of VO_{2max} in females (n = 16).

Time (Min : Sec)	Predicted VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)	Time (Min : Sec)	Predicted VO_{2max} ($ml \cdot kg^{-1} \cdot min^{-1}$)
01:00	21.3	07:00	32.9
02:00	23.2	08:00	34.8
03:00	25.1	09:00	36.7
04:00	27.1	10:00	38.7
05:00	29	11:00	40.6
06:00	30.9	12:00	42.5

4.4 Discussion

The aim of this investigation was to develop a progressive incremental rowing test (IRT) that accurately predicts maximal oxygen uptake in recreationally fit individuals with a VO_{2max} of around 20-50 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ using a nomogram (Table 4.4/4.5). The new IRT accurately predicts VO_{2max} and presents a linear relationship (r = 0.68) between an increase in VO_2 and work rate (Stroke rate). This relationship was stronger in females (r = 0.78; Fig 4.4) than males (r = 0.39; Fig 4.5) and a nomogram was created for each gender (Table 4.4/4.5) A linear relationship has been seen previously (r = 0.92) in work rate and VO_2 during running (Ramsbottom et al. 1988) which has been used as a predictor of VO_{2max}.

VO_{2max} was significantly higher in men (Table 4.1) during running than rowing which has been previously observed in rowers (Smith et al. 1994) however, Yoshiga & Higuchi (2003b) observed a larger VO_{2max} in rowers than runners due to increased body size and fat-free mass. A reduction in VO_{2max} during rowing has been suggested to be due to the cramped seated position of rowing which restricts the cardiorespiratory airways (Cunningham et al. 1975; Szal & Schoene, 1989; Rosiello et al. 1987). A significantly lower VE_{max} was observed in the IRT than running VO_{2max} which has been suggested to be due to exercise-induced arterial hypoxaemia (Nielsen. 2003) caused by ventilation and locomotion coupling (entrainment) at the stoke finish (Siegmund et al. 1999). As stroke rate increases it is possible that we see greater entrapment during each incremental stage during the protocol possibly causing a decrease in VO_{2max} (Smith et al. 1994).

HR_{max} was found to be higher at VO_{2max} in rowing than in running (*See section 4.3.2*). Previous studies have also observed HR_{max} to be higher in running than rowing (Yoshiga and Higuchi, 2002a; 2003a,b) which is again thought to be due to the seated position, restricting the body's ability of venous return and an elevated central blood volume.

The results showed no significant difference in rate of perceived exertion between the IRT and running VO_{2max} suggesting that participants were experiencing the same physical stress sensation throughout the both tests. It is thought that arm fatigue was the limiting factor in participants, previously suggested in inexperienced rowers (Bassett et al. 1984). A strong relationship was seen in 2,000m rowing performance times (*See section 4.3.4*) where participants with a higher VO_{2max} produced quicker times, similar in previous studies (Secher et al. 1982; Jurmiae et al. 2002; Ingham et al. 2002).

A linear relationship between oxygen consumption and economy has previously been seen during increased running speeds therefore, it is not surprising that we find that oxygen consumption increases linearly with increased stroke rate on an ergometer. A positive relationship has been observed between rowing economy and performance (Cosgrove et al, 1999). This suggests that oxygen consumption at set stroke rates can be used to assess rowing economy during the IRT similar to running speeds on a treadmill.

No significant difference was observed between blood lactate (B[la]) levels between both incremental exercise tests however, higher results were observed at the end of the 2,000m rowing time trial than both incremental exercise tests (Figure 4.2; table

4.2). This result is due to a longer period of time at a higher effort causing B[a] levels to rise within the first few minutes whereas in the exercise tests, B[la] would rise slowly with a Sharpe peak towards the end. B[la] was also taken from the finger which, during rowing exercise, could have had an effect on B[la] concentrations in the samples. Previous research has seen sampling values differ from several sampling sites including the toe, ear and fingertip (Dassonville et al, 1998). Forsyth & Farrally (2000) suggested that B[la] concentrations should be taken from the toe during rowing which would not affect the rowing action while exercising. No significant difference was observed between IRT and running VO_{2max} in B[la] final concentration values (Table 4.2) suggesting that both tests induced an equal amount of concentrations at maximal exhaustion.

4.5 Conclusion

The results of this study show that maximal oxygen uptake values can be predicted from the levels obtained by the IRT using the gender specific nomograms (Table 4.4/4.5). The development of this protocol also provide a test which can be complete on a concept II rowing ergometer, commonly found in most gymnasia. Future studies should focus on the development of stronger relationships with bigger sample sizes.

Chapter V. The validity of the multistage fitness test in active 8-12 year olds and recommendations for UK based young people (Study B)

5.1 Introduction

The multistage fitness test (MSFT) was introduced in 1982 by Leger & Boucher (1982), first used in the UK in 1988 (Ramsbottom et al, 1988) and provides participants with an estimated maximal oxygen uptake (VO_{2max}). It has since become very popular in schools because of its low cost and its limited need for equipment. Performance in the test has seen globally, a significant decline (Tomkinson & Olds, 2007). A decrease in MSFT performance by 0.8% has been reported in English children by two studies with a combined sample size of 12,621 9 to 10 year olds (Stratton et al, 2007; Sandercock et al, 2010).

Recently, the British Association of Sports Science (BASES) published an expert statement called 'the importance of young people's aerobic fitness for heath' (Tolfrey et al, 2012). The statement recommends that the MSFT is used for identifying low-fitness in young people. The cut off values suggested have been taken from Adegboye et al (2011) (Table 5.1) who used a large sample size of 4,500 children aged either 9 or 15 years in several different European countries including Denmark, Portugal, Estonia and Norway.

Table 5.1. Suggested cut off values in aerobic fitness for young people. (Taken from Adegboye et al (2011)

Age	Girls	Boys
8-11	37.4	43.6
11-14	33.0	46.0

Cut of values are $ml \cdot kg^{-1} \cdot min^{-1}$

Fitness test batteries have been developed to create a health-related set of skills for children to complete in order to assess an individual's fitness. There are many battery versions including the Eurofit (Europe) and Fitnessgram (USA) batteries. These batteries included several different ways of assessing levels of physical activity, including MSFT, hand grip dynamometer strength and standing broad jump performance. Height and weight are commonly recorded to produce BMI for measurement of body composition. Other forms of body composition measurements included waist circumference as well as triceps and subscapular skinfold thickness (Ruiz et al, 2011).

Body mass index (BMI) is a simple anthropometric measurement that is associated with cardiovascular disease. With this association, BMI can predict the risk of future cardiovascular and other metabolic diseases in young people. In previous studies, BMI has also been associated with young people and levels of physical activity (Aires et al, 2010; Hussey et al, 2007) as well as similar anthropometric measures include fat mass (% Kg), free fat mass (Kg) and total body water (Kg).

The first aim of this study was to observe any associations between the MSFT and performance variables including 10m and 40m sprints as well as hand grip and back dynamometer strength for validity. Relationships will be used to develop nomograms for the prediction of MSFT performance therefore, providing other measurements for the screening of active young people. Secondly, recommendations will be made for sports club leaders, coaches and teachers for the use of MSFT on screening 8-12 year olds.

5.2 Subjects and Experimental designs

Sixty active young people between the ages of 8-12 year olds (Boys, *n* = 25; Girls, *n* = 35) were recruited from a local athletics club. The club employs a non-specific event athletic policy until the age of 12 + therefore, young people have been previously exposed to all forms of physical active in athletics events including running, jumping and throwing. All testing was conducted on an indoor athletics straight at the Bedfordshire International Athletics Stadium. Ethics was approved by the University of Bedfordshire ethics committee (*See Appendix I*) and full up to date CRB checks were submitted for all regular coaches assisting in the testing procedures. Testing was conducted on Tuesday and Thursday evenings at 6-7.30 for several weeks during June/July 2012 to collect all data.

Height (Cm) was measured using a portable stadiometer (Seca, Leicester, Cranlea). Tanitia scales (BC41MA Segmental, Cranlea) were used to measure weight (Kg) , body mass index (BMI), fat %, fat mass (Kg) , free fat mass (Kg) and total body water (Kg). Isokinetic strength was measured using a back and leg digital dynamometer (Takei A5402) and a hand grip dynamometer (Takei A5401). Sprint speed was recorded using electronic light gates (Brower test centre systems, Cranlea). Aerobic fitness was assed using the MSFT (Ramsbottom et al, 1988). Final scores were calculated from the number of shuttle complete and recorded as in meters not the level achieved.

5.2.1 Statistical analyses

T-tests were used to look at the differences in performances and anthropometric variables between boys and girls. Relationships observed were analysed using a correlation analysis for relationships and a regression analysis for the creation of the nomogram tables (*For more information see section 3.5*). Statistical significance was accepted when $P < 0.05$.

5.3 Results

No significant differences were observed between mean age, height and weight in both gender groups (Table 5.2). No significant differences were observed in all anthropometric and performance data between both genders (Table 5.2).

Table 5.2. Mean ± SD for anthropometric and performance data in all subjects and gender groups.

	All Subjects (*n* = 60)	**Boys** (*n* = 25)	**Girls** (*n* = 35)
Age (Years)	10 ± 1.3	10 ± 1.2	10.1 ± 1.3
Height (Cm)	146.1 ± 11.1	145.6 ± 10.9	146.3 ± 11.3
Weight (Kg)	35.9 ± 8.5	35.6 ± 7.9	36.0 ± 9.0
Anthropometric Data			
BMI	17.2 ± 3.1	16.5 ± 2.0	17.5 ± 3.5
Fat % (%)	20.1 ± 4.6	18.6 ± 4.3	21.0 ± 4.6
Fat Mass (Kg)	7.5 ± 3.0	6.7 ± 5.2	7.9 ± 3.2
Free Fat Mass (Kg)	28.4 ± 6.2	28.9 ± 6.4	28.2 ± 6.2
Total Body Water (Kg)	21.0 ± 4.6	21.1 ± 4.7	20.9 ± 4.6
Performance Data			
10m Sprint (Sec)	2.24 ± 0.1	2.23 ± 0.1	2.25 ± 0.1
40m Sprint (Sec)	7.15 ± 0.7	7.12 ± 0.7	7.17 ± 0.7
Hand Grip (Kg)	18.1 ± 4.9	18.7 ± 5.0	17.6 ± 4.9
Pull (Kg)	42.5 ± 14.0	44.5 ± 14.5	41.1 ± 13.7
20m MSFT (Meters)	1240 ± 150	1240 ± 100	1240 ± 200

Table 5.3. Mean ± SD for all anthropometric and performance data in each linear age group (8, 9, 10, 11 and 12 years olds) category.

All Subjects	**8 Years** (*n* = 9)	**9 Years** (*n* = 8)	**10 Years** (*n* = 19)	**11 Years** (*n* = 16)	**12 Years** (*n* = 8)
Age (Years)	8 ± 0.0	9 ± 0.0	10 ± 0.0	11 ± 0.0	12 ± 0.0
Height (Cm)	130 ± 4.2	139 ± 8.1	143.5 ± 4.6	153.8 ± 8.1	157.5 ± 5.6
Weight (Kg)	23.9 ± 2.5	30.6 ± 3.4	33.8 ± 6.1	41.9 ± 5.7	44.2 ± 5.6
Anthropometric Data					
BMI	14.8 ± 2.0	16.6 ± 1.9	17.9 ± 4.7	17.6 ± 1.5	17.8 ± 2.4
Fat % (%)	17.4 ± 2.2	21 ± 5.3	20.9 ± 5.7	19.9 ± 4.0	21.3 ± 4.7
Fat Mass (Kg)	4.2 ± 0.8	6.6 ± 2.2	7.6 ± 3.3	8.5 ± 2.5	9.5 ± 2.6
Free Fat Mass (Kg)	19.7 ± 2.0	25.8 ± 2.2	26.7 ± 3.0	33.4 ± 3.9	34.6 ± 4.4
Total Body Water (.Kg)	14.4 ± 1.4	19.4 ± 4.3	19.6 ± 2.2	24.4 ± 2.8	25.3 ± 3.2
Performance Data					
10m Sprint (Sec)	2.45 ± 0.1	2.23 ± 0.1	2.21 ± 0.1	2.18 ± 0.1	2.24 ± 0.1
40m Sprint (Sec)	8.11 ± 0.6	7.07 ± 0.6	6.97 ± 0.6	6.96 ± 0.4	6.9 ± 0.7
Hand Grip (Kg)	11.7 ± 2.8	17.6 ± 3.0	16.5 ± 3.0	21.8 ± 3.7	22.0 ± 5.2
Pull (Kg)	28.6 ± 12.3	39.3 ± 11.7	40.4 ± 10.6	49.1 ± 11.7	53.3 ± 16.2
20m MSFT (Meters)	680 ± 100	1120 ± 200	1100 ± 180	1180 ± 200	1060 ± 140

Table 5.4. Mean ± SD in relationships between the MSFT and performance data for all subjects in gender groups.

	Regression Equation	***R* Value**	**R^2 Value**	***P* Value**	**Significance**
All Subjects (n = 60)					
10m Sprint	Y = - 1053 (x) 3441	- 0.4252	0.1808	0.0007	Yes ($P < 0.05$)
40m Sprint	Y = - 261 (x) 2943	- 0.4756	0.2262	0.0001	Yes ($P < 0.05$)
Back and leg dynamometer	Y = 11.25 (x) 594	0.40	0.1650	0.0013	Yes ($P < 0.05$)
Hand grip dynamometer	Y = 25.7 (x) 607	0.3290	0.2083	0.0103	Yes ($P < 0.05$)
Boys (n = 25)					
10m Sprint	Y = - 817 (x) 2896	-0.3591	0.1289	0.0779	No* ($P > 0.05$)
40m Sprint	Y = - 308 (x) 3262	-0.5753	0.3309	0.0026	Yes ($P < 0.05$)
Back and leg dynamometer	Y = 7.72 (x) 723	0.2938	0.08629	0.1541	No* ($P > 0.05$)
Hand grip dynamometer	Y = 23.5 (x) 625	0.3083	0.09507	0.1337	No* ($P > 0.05$)
Girls (n = 35)					
10m Sprint	Y = - 1272 (x) 3950	- 0.4804	0.2308	0.0035	Yes ($P < 0.05$)
40m Sprint	Y = - 229 (x) 2724	- 04099	0.1681	0.0145	Yes ($P < 0.05$)
Back and leg dynamometer	Y = 14.43 (x) 483	0.4955	0.2455	0.0025	Yes ($P < 0.05$)
Hand grip dynamometer	Y = 27.9 (x) 584	0.3488	0.2117	0.0400	Yes ($P < 0.05$)

*No significant relationship was observed ($P > 0.05$)

3.1 MSFT and performance relationships

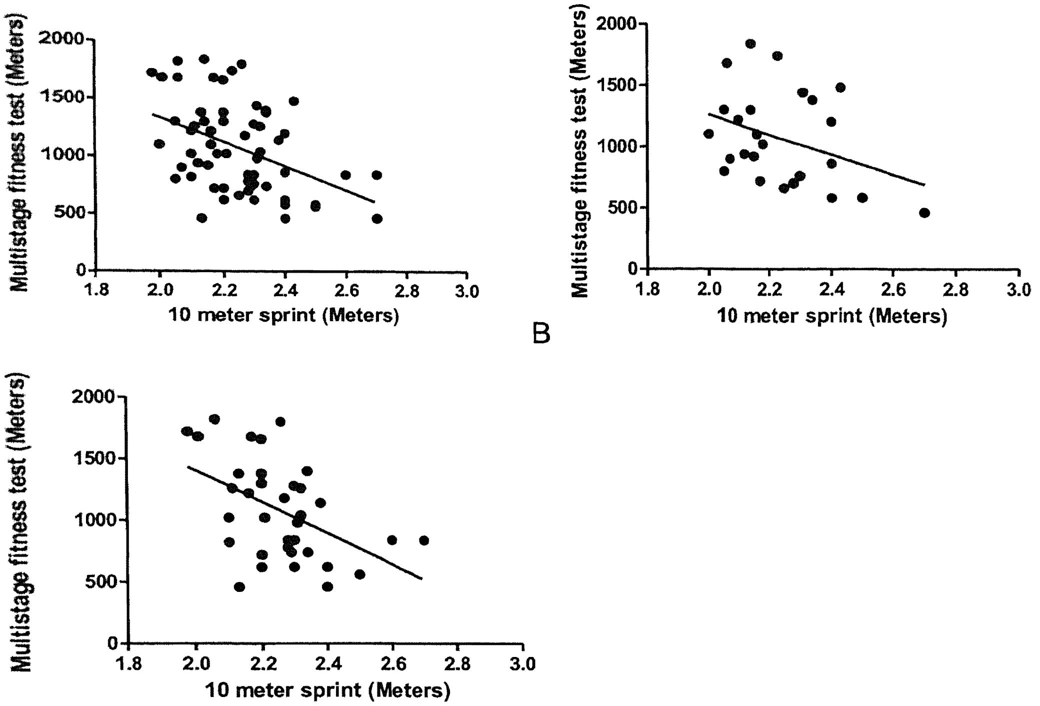


Figure 5.1. Relationship between MSFT and 10 m sprint time (A) All subjects (B) Boys (C) Girls.

Table 5.5. Nomogram for the prediction of MSFT scores from 10 m sprint time in all subjects and gender groups.

10 m Sprint performance (Seconds)	**All Subjects (*n* = 60)predicted MSFT distance (Meters)**	**Boys (*n* = 25) predicted MSFT distance (Meters)**	**Girls (*n* = 35) predicted MSFT distance (Meters)**
2.80	492	608	388
2.70	597	690	515
2.60	702	771	642
2.50	808	853	770
2.40	913	935	897
2.30	1019	1016	1024
2.20	1124	1098	1151
2.10	1229	1180	1278
2.00	1335	1262	1460

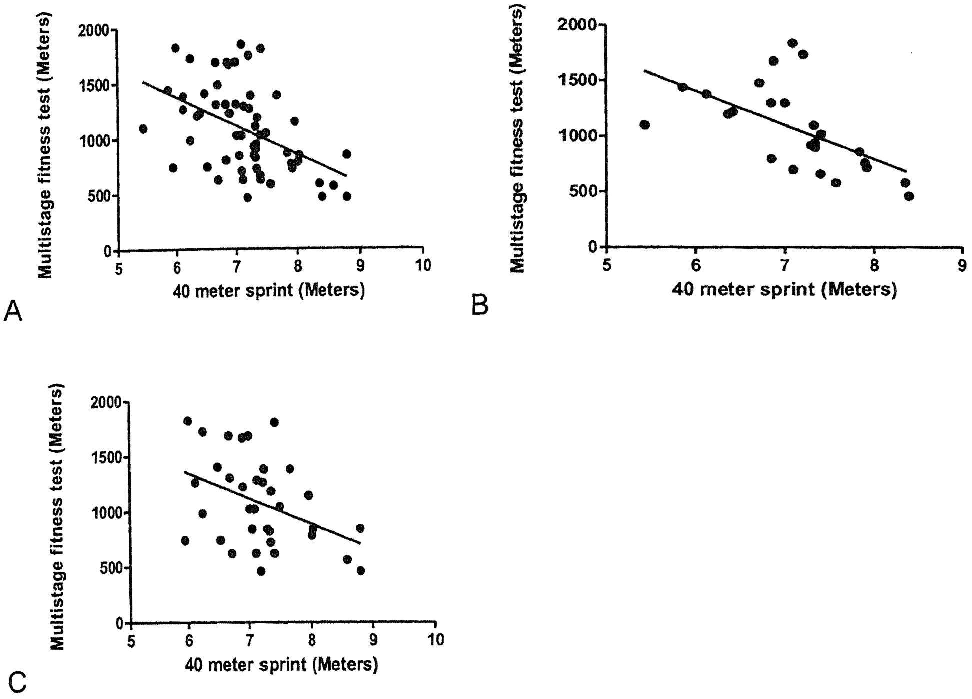
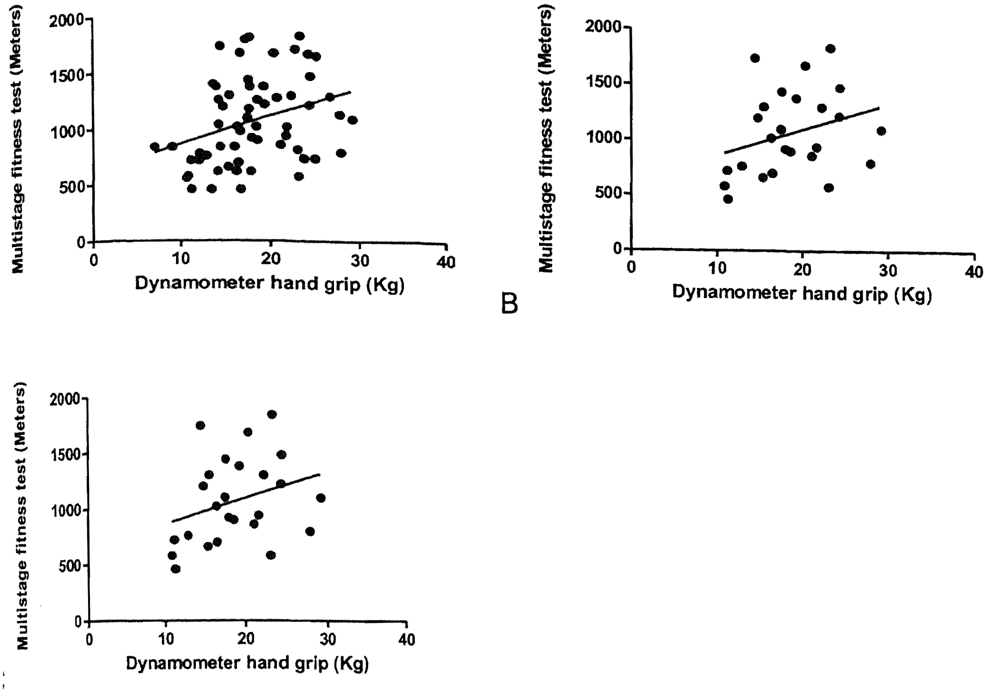


Figure 5.2. Relationship between MSFT scores and 40 m sprint time (A) All subjects (B) Boys (C) Girls

Table 5.6. Nomogram for the prediction of MSFT scores from 40 m sprint time in all subjects and gender groups

40 m Sprint performance (Seconds)	**All Subjects (*n* = 60)predicted MSFT distance (Meters)**	**Boys (*n* = 25) predicted MSFT distance (Meters)**	**Girls (*n* = 35) predicted MSFT distance (Meters)**
9,00	594	490	663
8.50	724	644	777
8.00	855	798	892
7.50	985	952	1006
7.00	1116	1106	1121
6.50	1246	1260	1235
6.00	1377	1414	1350
5.50	1507	1568	1464
5.00	1638	1727	1579



igure 5.3. Relationship between MSFT scores and hand grip dynamometer scores

A) All subjects (B) Boys (C) Girls

able 5.7. Nomogram for the prediction of MSFT scores from hand grip

ynamometer scores in all subjects and gender groups.

Dynamometer hand grip performance (Kg)	All Subjects (*n* = 60)predicted MSFT distance (Meters)	Boys (*n* = 25) predicted MSFT distance (Meters)	Girls (*n* = 35) predicted MSFT distance (Meters)
10	864	860	863
12	915	907	918
14	966	954	974
16	1018	1001	1030
18	1069	1048	1086
20	1121	1095	1142

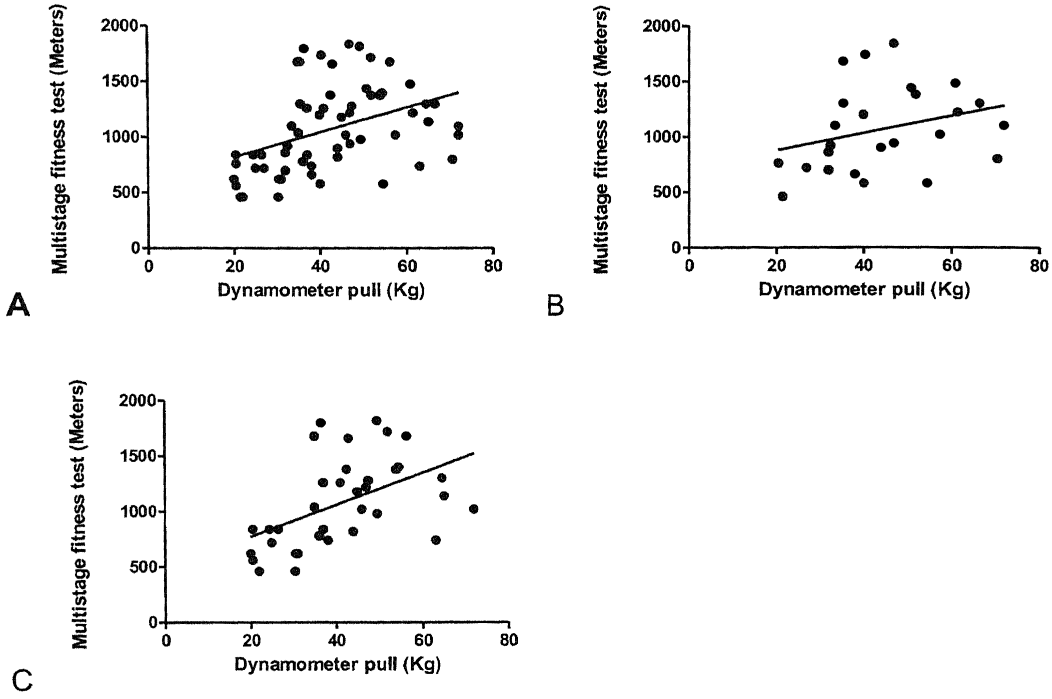


Figure 5.4. Relationship between MSFT scores and pull dynamometer scores (A) All subjects (B) Boys (Girls)

Table 5.8. Nomogram for the prediction of MSFT scores from pull dynamometer scores in all subjects and gender groups.

Dynamometer pull performance (Kg)	**All Subjects (*n* = 60)predicted MSFT distance (Meters)**	**Boys (*n* = 25) predicted MSFT distance (Meters)**	**Girls (*n* = 35) predicted MSFT distance (Meters)**
10	706	800	627
20	891	877	771
30	931	954	915
40	1044	1034	1060
50	1156	1109	1204
60	1269	1186	1348
70	1381	1263	1493

5.4 Discussion

The aim of this investigation was to assess the validity and relationships between several speed and strength variables to develop nomograms for the prediction of MSFT performance. The study was also to develop suggested recommendation protocol guidelines for future testing young people in schools and sports clubs as well as scientific data collection.

In sixty 8-12 year olds, MSFT distance averaged 1240m (Table 5.2) for both genders therefore, no significant difference was observed in the final average scores. MSFT results linearly increased with age from 680m (8 year olds) to 1060m (12 year olds) with the greatest distance covered by 11 year olds in 1180m (Table 5.3).

Little research has looked at the relationship between a single sprint and a MSFT score in a young person. Significant relationships were observed in all subjects in both 10m (Figure 5.1; $r = -0.42$, $P < 0.05$) and 40m (Figure 5.2; .$r = -0.47$, $P < 0.05$) sprint times. Significant relationships were also observed in gender specific groups for 40m sprint in both boys (Figure 5.2; $r = -0.57$, $P < 0.05$) and girls (Figure 5.2; .$r = -0.40$, $P < 0.05$) however, only girls had a significant relationship in 10m sprint performance (Figure 5.1; $r = 0.48$, $P < 0.05$) whereas boys did not (Figure 5.1; $r = -0.35$, $P > 0.05$). From these results it can be suggested that MSFT performance can be accurately predicted in girls from both 10m and 40m sprint times using their specific gender group nomograms (Tables 5.5 & 5.6) however, only the 40m sprint nomogram provides an accurate prediction of VO_{2max} in boys (Table 5.6). This can be seen in the very strong relationship between MSFT and 40m (*r* = - 0.57) sprint correlations and the 10m (*r* = - 0.35) sprint correlations.

Maximal isometric strength was measured using hand grip dynamometry. The hand grip dynamometer is an easily administered piece of equipment with quick results. A relationship between MSFT scores and maximal hang grip strength was significant in all subjects (Figure 5.3; $r = 0.40$; $P < 0.05$) and girls (Figure 5.3; $r = 0.49$; $P < 0.05$) however, not significant in boys (Figure 5.3; $r = 0.29$; $P > 0.05$). A nomogram was created for the prediction of MSFT results from hang grip strength between the values of 10-20kg (Table 5.7). Although no significant relationship was observed in boys, hand grip strength scores increased linearly (8 Years old 11.7 ± 2.8 to 12 Years old 22 ± 5.2; Table 5.3) with no significant difference in final average scores for all ages, across both genders (Table 5.3). Strong evidence has been reviewed to suggest that hand grip strength is a valid measure of musculoskeletal fitness (Castro-Pinero et al, 2010) with norms for grip strength in children having been evaluated in 530 Swedish 4-16 year olds (Hager-Ross & Rosblad, 2002). The observation of an increase in hand grip strength was seen approximately parallel for both boys and girls until the ages of 10 years thereafter, boys were significantly stronger. Hager-Ross & Rosblad (2002) also found a significant relationship between hand grip strength and anthropometric variables including height ($r = 0.90$) and weight ($r = 0.90$). Similarly, although not as strong, we also observed significant relationships between hang grip strength and height ($r = 0.66$; $P < 0.0001$), weight ($r = 0.68$; $P < 0.0001$) in all sixty subjects.

Measuring hand grip strength does however, come with several adjusting variables. Several studies have shown results that suggest grip span should be measured before measuring hand grip strength in young people aged 6-12 years old (Espana-Romero et al, 2008) and also teenagers aged 13 - 18 years (Ruiz et al, 2006). In our study, hand grip size was not measured however, was adjusted to suite the young person.

Little research has been conducted in back and leg dynamometer performance on young people. Strength increases with age in young people. Milliken et al (2008) suggested several ways of assessing strength in young people including BMI, hand grip, long jump and a vertical strength test. They were all found to be related to one rep max strength in children. The authors suggest that these variables can be used to assess muscular fitness in young people in future studies. Our study showed that hand grip dynamometer strength was related to the MSFT in both genders (Table 5.4; $r = 0.40$, $P < 0.005$) however, the back and leg dynamometer test failed to show any relationship in boys between the MSFT (Table 5.8; ; $r = 0.29$, $P > 0.05$) but did show a relationship in girls (Table 5.8; $r = 0.49$, $P < 0.005$). A nomogram for the prediction of MSFT scores from back and leg dynamometer scores were created (Table 5.8). The dynamometer scores did show a very significant relationship between free fat mass (Table 5.4; $r = .68$, $P < 0.0001$), with a stronger relationship observed in girls (Table 5.4; $r = 0.71$, $P < 0.0001$) than in boys (Table 5.4; $r = 0.61$, $P = < 0.005$).

Free-fat mass (FFM) is a major predictor of muscle strength and suggests good bone mineral content in young people. Studies have shown that FFM can be predicted from other methods such as skin fold callipers results in health young people (Boye et al, 2002). Large scale studies focusing on FFM include Moliner-Urdiales et al (2010) who looked at the association of FFM on physical activity in 363 12-17 year olds. Boys had greater muscle strength which correlated to FFM and levels of physical activity however, girls did not. We observed a linearly increase in FFM all the way through each age group (Table 5.3) (8-12 years olds) and unlike Moliner-Urdiales et al (2010), there was no significant difference between each gender group as a whole (Table 5.2). Fat % and Fat mass were however, lower in boys than in girls with no significant difference observed.

5.5 Recommended protocol for testing young people

1.Informed consent

It is essential that ethics is approved by the appropriate institution and informed consent is signed by parents (Guardian) before any testing begins. BASES expert guidelines also recommend that willingness to participant from every young person is also confirmed (Williams et al, 2011). Full criminal recorded bureau (CRB check) are required before any testing can begin.

2.Time of day

All testing in this study was conducted after school hours between 18:00 – 19:30. Many young children complete physical activity after school hours (Post 15:00) in after school club and out of schools sports teams.

3. Surface

It is advised that the MSFT is completed on a hard surface due to the turn at the end of each 20m shuttle run. If it is not and is completed on grass, care should be taken when turning at the end of each 20m shuttle. All academic testing for the validity of the MSFT has been complete on a hard surface therefore, the reliability of results are reduced. During this study, all testing was completed indoors on an athletics track straight. It is advised that fitness testing is completed indoors and on a hard surface. This provides the best environment for reliable results however, these environments are not always available.

4.Warm up

Before any vigorous physical activity takes place, a progressive warm up should be included. An easy few minutes jogging is strongly advised followed by a short period of dynamic drills (5-8 minutes). These dynamic drills, often neglected, work on balance, co-ordination, neuromuscular function and running style.

5.Test battery

There are many different types of test batteries as described earlier (*Section 2.4.2*). It is important that the correct activities are selected for the appropriate age group or sports specific group. The MSFT is commonly seen in most test batteries as it minimise risk rather than a real VO_{2max} test. It can also accommodate large groups in a short amount of time and is valid in young people.

6. Test order

The order of testing is very important as it can have severe implications to the results. In this study we began with the paper work (Consent forms) and anthropometric measurements. After a short warm up, 10m and 40m sprint time was individually recorded while young people's heart rates were still high and plenty of anaerobic energy was still available. Strength tests (Hand grip and pull dynamometer) were then complete to give young people a short break before testing finished off with the MSFT. Testing finished off with the MSFT because young people should be running to maximal exhaustion.

7. Recovery time

Recovery time between each activity is very important as it ensures that the best possible scores are recorded however, the test battery doesn't want to go on for too long otherwise young people naturally get tired or bored. It is recommended that an hour and a half is sufficient to successfully complete all sprint tests, strength test and MSFT. Recovery time should not be static but active walking and standing while taking on fluids.

8. Feedback

Anthropometric data was not given to young people unless parents requested it whereas performance data was given. Sports coaches, teachers and researchers should be careful when giving out feedback for ethical reasons.

9. Re-test

A useful way of identifying fitness improvements or consistency over a period of times is to complete the same tests again a few weeks later called a re-test. A long enough should be allowed for training adaptation but should not last too long that a maturation adaptation takes place. Therefore, it is suggested that a period of 4-6 weeks is appropriate for re-test assuming young people are regularly taking part in physical activity.

5.6 Conclusion

The results of this study provide new ways of predicting MSFT results using several performance measurements in 8-12 year olds. Nomograms have been created (Tables 5.5, 5.6, 5.7, 5.8) which can be applied in schools or sports clubs to predicting MSFT results and used to monitor young people's development and maturation. Girls were found to have stronger relationships in MSFT prediction which must be taken into account when used in clubs and schools. It is advised to use the 40m sprint test as it provides the best predictor of MSFT results in both genders. Future research should try to use greater sample sizes and test-re-test studies should be conducted in assessing the reliability of these prediction equations.

CHAPTER VI GENERAL DISCUSSION

This chapter will be presented in three sections. Firstly, the principle findings of each experimental chapters will be presented. Secondly, the practical applicator of the findings in each experimental chapter will be summarized.

9.1. Principle findings and practical application

9.1.1 Rowing MSFT (Chapter IV)

1. The newly developed Rowing MSFT is a valid test that provides a linear relationship between work rate and VO_2. This linear relationship can be seen in both genders and confirms the original hypothesis by using the stroke rate method. The gender predictive nomograms (Figure 4.4/4.5) provide accurate, valid predictions of VO_{2max} on a rowing ergometer. The nomograms do not however, provide accurate predictions of VO_{2max} for any other exercise modes as we have shown running VO_{2max} to be significantly higher. The test can now be used in gyms by applying a headset for the audio bleep to monitor fitness. It is also a alterative for a client who cannot or would prefer not to run as the test is based on a seated rowing ergometer.

2. One of the main physiological findings was that heart rate and VO_2 were lower in rowing than in running throughout the incremental tests. It is suggest that this is due

to the cramped position of rowing, restricting the cardiorespiratory airways and creating blood pooling, reducing venous return.

9.1.2 MSFT in 8-12 year olds (Chapter V)

1. The second experimental study aimed to identify relationships between the MSFT and other strength and speed variables as well as several anthropometric variables in young people. Relationships were successful in both speed and strength for girls however, in boys significant relationships were only observed between the MSFT and 40m sprint performance (Figure 5.2; Table 5.6.).
2. In addition, this study has shown that the MSFT provides valid results and can be used to predict VO_{2max} in young people however, we speculate based upon these results that the predicted validity of VO_{2max} is stronger in girls than boys. This may be due to several factors incluing age, maturation and a smaller subject size in boys (*n* = 25) compared to girls (*n* = 35).

9.2 Future study recommendations

The development of the new rowing MFST has provided a range of future studies which could be conducted. It is suggested that in the future, a range of intervention studies using the MSFT as a marker for VO_{2max} in gym users are conducted. Interventions can include longitudinal studies, strength and conditioning programmes for sedentary subjects as well as clinical population groups and extreme environmental conditions. The mechanism for lower heart rates in rowing should also be re-investigated with the possibly of interventions to improve heart rates. One intervention maybe upper body compression garments which has been seen to improve venous return and increase recovery and performance (MacRae et al, 2011) however, no work has been done on upper body compression garments in rowers.

Problems developed from the initial MSFT work need to be solved in the future including a bigger sample size however, the main issue is the amount of force produced in the test. The amount of force generated during each stroke should be monitored to ensure that a linear increase is observed which will created a more accurate test. Without this information stroke rate maybe increasing however, force production may not increase. This could provide a guide for coaches and performers on which areas of the body are weaker. The stroke rate based protocol could also be developed into a more elitist product/protocol, not focused on VO_{2max} but rowing economy. Bleep stage lengths could be extended and 30 second B[la] breaks could be included to observe rowing economy in elite rowers at a set stroke rate using the audio signal as a pacemaker. This kind of work could have big implications in the assessment of rowers and focus on the amount of VO_2 rowers consume at set stroke rates. Finally, VO_{2max} during cycling could be used to compare to rowing instead of running as it is more relative to rowing with the consideration of body mass. Although a true VO_{2max} will not be observed in cycling, this does reduce the chance of a significant difference between VO_{2max} test methods.

The work in young people, similar to the rowing MSFT, provides a range of future studies which could be conducted including several intervention studies, using bigger samples sizes and a focus on the relationship between the MSFT and 40m Sprint performance. The possibility of a valid test for the prediction of VO_{2max} using one 40m sprint test could be very useful in young people as well as adults. Due to the test being a maximal 40m sprint it would only be used in health populations.

9.3 Conclusions

It was hypothesized that a linear relationship between VO_{2max} and work rate would be observed during an incremental rowing test. Using an incremental stroke rate based rowing protocol, a successful observation in forty one gym users was observed. An audio signal was used for the regulation of stroke rate and a nomogram created from the results successfully predicts VO_{2max} around 20-50 $ml\cdot kg^{-1}\cdot min^{-1}$.

The validity of the MSFT has been tested in sixty active young people from a local athletics club. The MSFT provides valid predictive measurements of VO_{2max} when compared to several other sprint and strength performance measurements. Nomogarms were also created to predict MSFT results from sprint and strength variables. These performance measurements could be used if a MSFT is unavailable or a battery of fitness tests is being conducted. Recommendations into conducting a successful battery of fitness test in young people have been suggested.

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Appendix I. Ethics forms for both study A and B

UNIVERSITY OF BEDFORDSHIRE

Research Ethics Scrutiny (Annex to RS1 form)

SECTION A To be completed by the candidate

Registration No: 0802988

Candidate: Alan Metcalfe

Research Institute: ISPAR

Research Topic: The development of indoor fitness tests for rowing and cycling

External Funding: Yes

The candidate is required to summarise in the box below the ethical issues involved in the research proposal and how they will be addressed. In any proposal involving human participants the following should be provided:

- clear explanation of how informed consent will be obtained,
- how will confidentiality and anonymity be observed,
- how will the nature of the research, its purpose and the means of dissemination of the outcomes be communicated to participants,
- how personal data will be stored and secured
- if participants are being placed under any form of stress (physical or mental) identify what steps are being taken to minimise risk

If protocols are being used that have already received University Research Ethics Committee (UREC) ethical approval then please specify. Roles of any collaborating institutions should be clearly identified. Reference should be made to the appropriate professional body code of practice.

A finger prick, capillary blood sample will be obtained from each of the subjects at the beginning and end of each test. This will follow the standard procedure outlined in the ISPAR generic ethics document. This is a routine procedure that bears minimal risks. Blood samples will be disposed of immediately after analysis and will not be stored for any period of time. These measures are required to establish participant has exercised to max.

Vigorous exercise (maximal incremental test to exhaustion and newly designed multi-stage fitness tests) will be performed as part of this study. The subjects for this research will be from a variety of trained/ non-trained, healthy population, and between the ages of 18-45. As such, these exercise conditions will bear no additional risks to the subjects to those by the exercise they regularly engage in.

Clear explanation of how informed consent will be obtained

A subject information sheet will be provided for every subject detailing the protocol and requirements for each test. Subjects will also be required to complete an informed consent form before any testing can begin. The researcher will ensure there are no issues which arise from these forms, if so, will direct accordingly.

How will confidentiality and anonymity be observed

All participants will receive information letters detailing them of the test procedures and information about the data being collected. Participants will only receive information in accordance to their specific tests. All information is given on a voluntarily basis and therefore, no pressure should be given if a participant does not wish to supply certain details. Participants will be made aware that there is a possibility that the study maybe published, but that their anonymity will remain.

How will the nature of the research, its purpose and the means of dissemination of the outcomes be communicated to participants

Information letters to participants will outline what information is being collected and the purpose of all test procedures. The participants will receive information related to their tests only. It is clearly stated that all information is voluntarily given and there are no repercussions should a participant not wish to supply certain details. Participants will be made aware that there is a possibility that the study may be published, but that their anonymity will remain.

How personal data will be stored and secured

Data will be stored by Alan Metcalfe, away in locked draws for security for the duration of the project. Once the data has been analysed it will be destroyed. Personal information from the project will only be used for the necessary analysis of data.

If participants are being placed under any form of stress (physical or mental) identify what steps are being taken to minimise risk

Participants will be required to complete maximal exercise testing therefore, creating discomfort. All measures to avoid any unnecessary discomfort will be taken. A full warm-up and cool-down will be applied to significantly reduce the chance to injury and risk to the participant. The exercise required in this research project poses little risk or discomfort for participants who are regularly used to exercise training.

Answer the following question by deleting as appropriate:

1. Does the study involve vulnerable participants or those unable to give informed consent (e.g. children, people with learning disabilities, your own students)?

   ~~Yes~~ No

2. Will the study require permission of a gatekeeper for access to participants (e.g. schools, self-help groups, residential homes)?

   ~~Yes~~ No

3. Will it be necessary for participants to be involved without consent (e.g. covert observation in non-public places)?

   ~~Yes~~ **No**

4. Will the study involve sensitive topics (e.g. sexual activity, substance abuse)?

   ~~Yes~~ **No**

5. Will blood or tissue samples be taken from participants?

   Yes ~~No~~

6. Will the research involve intrusive interventions (e.g. drugs, hypnosis, physical exercise)?

   Yes ~~No~~

7. Will financial or other inducements be offered to participants (except reasonable expenses)?

   ~~Yes~~ **No**

8. Will the research investigate any aspect of illegal activity?

   ~~Yes~~ **No**

9. Will participants be stressed beyond what is normal for them?

   ~~Yes~~ **No**

10. Will the study involve participants from the NHS (e.g. patients or staff)?

    ~~Yes*~~ **No**

If you have answered yes to any of the above questions or if you consider that there are other significant ethical issues then details should be included in your summary above. If you have answered yes to Question 1 then a clear justification for the importance of the research must be provided.

*Please note if the answer to Question 10 is yes then the proposal should be submitted through **NHS research ethics approval procedures** to the appropriate **COREC**. The UREC should be informed of the outcome.

Checklist of documents which should be included:

Project proposal (with details of methodology) & source of funding	
Documentation seeking informed consent (if appropriate)	
Information sheet for participants (if appropriate)	
Questionnaire (if appropriate)	

(Tick as appropriate)

Signature of Applicant: Alan Metcalfe Date: 25/10/11

Signature of Director of Studies:

Brewer

Date: 27th October 2011

This form together with a copy of the research proposal should be submitted to the Research Institute Director for consideration by the Research Institute Ethics Committee/Panel

UNIVERSITY OF BEDFORDSHIRE

Research Ethics Scrutiny (Annex to RS1 form)

SECTION A To be completed by the candidate

Registration No: 0802988

Candidate: Alan Metcalfe

Research Institute: ISPAR

Research Topic: The development of an exercise testing battery for children.

External Funding: Yes

The candidate is required to summarise in the box below the ethical issues involved in the research proposal and how they will be addressed. In any proposal involving human participants the following should be provided:

- clear explanation of how informed consent will be obtained,
- how will confidentiality and anonymity be observed,
- how will the nature of the research, its purpose and the means of dissemination of the outcomes be communicated to participants,
- how personal data will be stored and secured
- if participants are being placed under any form of stress (physical or mental) identify what steps are being taken to minimise risk

If protocols are being used that have already received University Research Ethics Committee (UREC) ethical approval then please specify. Roles of any collaborating institutions should be clearly identified. Reference should be made to the appropriate professional body code of practice.

Active children (regularly attending athletics coaching sessions) will complete a set of exercise battery tests which are commonly used in children aged 8-12. As such, these exercise conditions will bear no additional risks to the subjects to those by the exercise they regularly engage in. The physical activity tests will be recorded by a minimum of two members of the research team and will have full CRB clearance. An activity questionnaire (PAQ-C) will also be completed as well as a number of anthropometric measures including age, height, weight and BMI. All activity will take place indoors at the Bedford International Athletics Stadium (BIAS). Clearance will be granted from BIAS to ensure data collection can commence.

Clear explanation of how informed consent will be obtained

A subject information sheet will be provided for every parent detailing the protocol and requirements for completing the battery of tests. Parents will also be required to read and sign an informed consent form before any testing can begin. The researcher will ensure there are no issues which arise from these forms, if so, will direct accordingly.

How will the nature of the research, its purpose and the means of dissemination of the outcomes be communicated to participants

Information letters for parents will outline what information is being collected and the purpose of all test procedures. Parents will receive information related to their tests only. It is clearly stated that all information is voluntarily given and there are no repercussions should a participant not wish to supply certain details. Parents will be made aware that there is a possibility that the study may be published, but that their anonymity will remain.

How personal data will be stored and secured

Data will be stored by Alan Metcalfe, away in locked draws for security for the duration of the project. Once the data has been analysed it will be destroyed. Personal information from the project will only be used for the necessary analysis of data.

If participants are being placed under any form of stress (physical or mental) identify what steps are being taken to minimise risk

Children will be required to complete activity's that they are regularly engaged in (Running, jumping and throwing) therefore, creating discomfort. All measures to avoid any unnecessary discomfort will be taken. A full warm-up and cool-down will be applied to significantly reduce the chance to injury and risk to the participant. The exercise required in this research project poses little risk or discomfort for participants who are regularly used to exercise training.

Answer the following question by deleting as appropriate:

11. Does the study involve vulnerable participants or those unable to give informed consent (e.g. children, people with learning disabilities, your own students)?
Yes ~~**No**~~

12. Will the study require permission of a gatekeeper for access to participants (e.g. schools, self-help groups, residential homes)?
~~**Yes**~~ **No**

13. Will it be necessary for participants to be involved without consent (e.g. covert observation in non-public places)?
~~**Yes**~~ **No**

14. Will the study involve sensitive topics (e.g. sexual activity, substance abuse)?
~~**Yes**~~ **No**

15. Will blood or tissue samples be taken from participants?
~~**Yes**~~ **No**

16. Will the research involve intrusive interventions (e.g. drugs, hypnosis, physical exercise)?
Yes ~~**No**~~

17. Will financial or other inducements be offered to participants (except reasonable expenses)?
~~**Yes**~~ **No**

18. Will the research investigate any aspect of illegal activity?
~~Yes~~ **No**

19. Will participants be stressed beyond what is normal for them?
~~Yes~~ **No**

20. Will the study involve participants from the NHS (e.g. patients or staff)?
~~Yes*~~ **No**

If you have answered yes to any of the above questions or if you consider that there are other significant ethical issues then details should be included in your summary above. If you have answered yes to Question 1 then a clear justification for the importance of the research must be provided.

*Please note if the answer to Question 10 is yes then the proposal should be submitted through **NHS research ethics approval procedures** to the appropriate **COREC**. The UREC should be informed of the outcome.

Checklist of documents which should be included:

Project proposal (with details of methodology) & source of funding	
Documentation seeking informed consent (if appropriate)	
Information sheet for participants (if appropriate)	
Questionnaire (if appropriate)	

(Tick as appropriate)

Signature of Applicant: Alan Metcalfe Date: 27/06/12

Signature of Director of Studies:

Tim Brewer

Date: 27th June 2012

Appendix II. Rowing MSFT data collection sheets

Traditional V0$_{2max}$ Test

1. Complete a PARQ, subject information sheet and blood sheet. Take a pre B[la] measurement before the start of exercise.
2. Subject warm up on treadmill at chosen speed for 3 minutes.
3. Select subject on cortex and insert data required. Attach HR monitor and mask to subject.
4. The test begins with the subject running at the starting speed (8km.h-1) and set gradient at 1%. Start the cortex and data collection.
5. Increase the speed by **1km·h-1** every **2 minutes** until volitional exhaustion (Should occur between 8-12 minutes). Record VO$_2$, HR, VE and RER every minutes. Record RPE during the last 15 seconds of each stage.
6. Once exhaustion has been reached stop the measurement of the cortex and remove mask. Allow subject to cool-down after a post B[la] sample. Ensure the mask is correctly cleaned.

Subject- Age- Sex- Height-

Weight- Pre B[la]-

Time (Min)	Speed (km/h)	V0$_2$ (mL/kg/min)	VE (L/min)	HR (b/min)	RER	RPE
0-2						
2-4						
4-6						
6-8						
8-10						
10-12						

12-14						

Time to exhaustion- Post B[la]-

Rowing multi stage fitness test

1. Complete a PARQ, subject information sheet and blood sheet before pre B[la] measurement.
2. Allow subject a 3 minute warm up at a selected rowing intensity.
3. Select subject on cortex and attach HR monitor and mask to subject. For all rowing resistance is set on **5 for Females and 10 for Males**
4. 'Priming Bout'-Start 500m row at select intensity (24 strokes per min for females/ 28 strokes per min for males) regulated using bleep. **NOTE**- 2 bleeps per whole stroke at this point therefore, 1 bleep for every half a stroke.

24 strokes per min= 48
28 strokes per min= 56

Pre B[la]-

Distance (m)	Time (min:sec)	V0$_2$ (mL/kg/min)	HR	RPE
500m				

Post B[la]-

5. Once 500m has been achieved subject then rests in position for 1 min before starting the multi stage fitness test.
6. The multi stage fitness test begins (next page) very slow and increases by 1 stroke per min or 2 increments on the metronome every 30 seconds.
7. At **8 minutes** into the test the metronome only increases by 1 increment and subject completes 1 stroke per bleep (You will have to decrease back to 30 on the metronome). The stages also increase in length from **30 seconds to 1 minute**.
8. The subject stops when they are exhausted or stroke rate can no longer be maintained. Ensure B[la] is taken as soon as possible after the subject has finished.

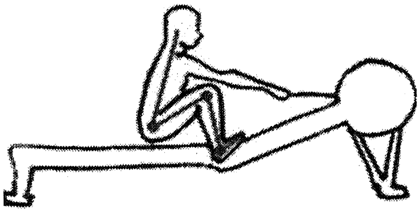
Subject- Age- Sex-

Height- Weight-

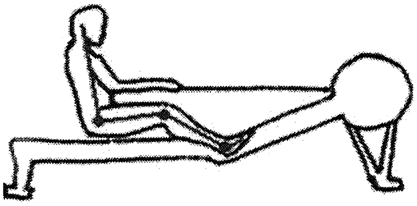
Time (min)	Pace	Metronome	VO_2 (mL/kg/min)	HR	RPE
30	15	30 (2)			
1:00	16	32 (2)			
1:30	17	34 (2)			
2:00	18	36 (2)			
2:30	19	38 (2)			
3:00	20	40 (2)			
3:30	21	42 (2)			
4:00	22	44 (2)			
4:30	23	46 (2)			
5:00	24	48 (2)			
5:30	25	50 (2)			
6:00	26	52 (2)			
6:30	27	54 (2)			
7:00	28	56 (2)			
7:30	29	58 (2)			
8:00	30	30			
9:00	31	31			
10:00	32	32			
11:00	33	33			
12:00	34	34			
13:00	35	35			
14:00	36	36			
15:00	37	37			
16:00	38	38			
17:00	39	39			
18:00	40	40			

Time to exhaustion- B[la] post-

APPENDIX III. Rowing stroke

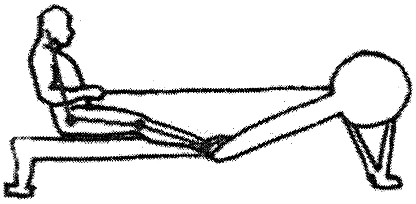


The catch lean slightly forward with your arms straight and shins almost vertical.



The drive

Press down your legs, gradually lean back and finish pulling with your arms (elbows going back).

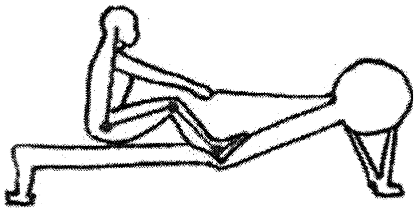


The finish

Finish with your legs straight, arms bent with you upper arms by your torso and the rowing handle at your abdomen.

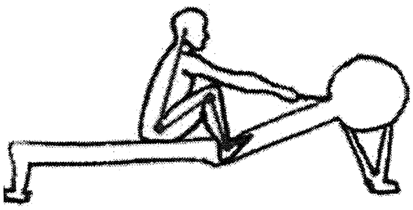
The recovery

Straighten your arms, lean forward from the hips, then bend your knees to slide forward.



Return to the catch (1)

ready for the next stroke



APPENDIX IV. Study A participant consent sheet and information sheet

TO BE COMPLETED BY PARTICIPANT

NAME:..(Participant)

I have read the Information Sheet concerning this project and understand what it is about. All my further questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:

- My participation in the project is entirely voluntary and I am free to withdraw from the project at any time without disadvantage or prejudice.

- I will be required to attend 3 sessions to complete the project.

- As part of the study I will have to:
  - Perform a treadmill based progressive exercise test to exhaustion ($V0_{2max}$ test).
  - Have my VO_2 measured during the test to exhaustion, involving a mask being attached to my face.
  - Perform a 2,000m row as fast as you can.
  - Complete the new multi stage fitness test on the rowing ergometer.

- I am aware of any risks that may be involved with the project.

- All information and data collected will be held securely at the University indefinitely. The results of the study may be published but my anonymity will be preserved.

Signed:...................................... (Participant) Date: ....

INFORMATION SHEET

The development of an indoor fitness test for rowing and cycling

Dear Participant,

Thank you for showing an interest in participating in this study. Please read this information sheet carefully before deciding whether to participate. If you decide to volunteer we thank you for your participation. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the aim of the project?

The purpose of the study is to develop an indoor multi-stage rowing and cycling fitness test that can predict VO_{2max}.

What type of participant is needed?

I am looking for male or, fit individuals (exercising at least 3 times a week – run/cycle/gym/sports club) who are between the ages of 18- 45.

What will participants be asked to do?

Should you agree to participate, you will be asked to come into the labs on three occasions. On the first, you will have an opportunity to familiarize yourself with the equipment that we will use for the testing procedures and undertake two initial exercise tests. The first of these will be a VO_{2max} test on a bicycle or treadmill (Depending on Rowing or Cycling MFT). This is a test of your aerobic capacity and lasts approximately 10 minutes. You will be asked to cycle or run for as long as possible, whilst the difficulty gradually increases. A small figure tip blood sample will be taken post 5 minutes after the end of the test to ensure a max was reached.

After completing this, you will then return to the labs approximately 3-5 days later to complete the newly designed multi-stage fitness test for rowing or cycling. You will be asked to row or cycle for as long as possible, while the stage bleep increases. Again, a small figure tip blood sample will be taken to ensure a maximal effort was achieved. After completing this, you will again return for your final visit to complete either a 10 mile TT or 2,000m row. This will be complete as fast as possible therefore, aerobic strain will be seen.

What are the possible risks of taking part in the study?

There are no risks with this study other than those associated with normal vigorous exercise.

What if you decide you want to withdraw from the project?

If, at any stage you wish to leave the project, then you can. There is no problem should you wish to stop taking part and it is entirely up to you. There will be no disadvantage to yourself should you wish to withdraw.

What will happen to the data and information collected?

Everyone that takes part in the study will receive their own results for the tests that they complete. All information and results collected will be held securely at the University of Bedfordshire and will only be accessible to related University staff. Results of this project may be published, but any data included will in no way be linked to any specific participant. Your anonymity will be preserved.

What if I have any questions?

Questions are always welcome and you should feel free to ask myself, Alan Metcalfe any questions at anytime. See details below for specific contact details.

Should you want to participate in this study then please complete the attached consent form, which needs to be returned before commencing the study.

This project has been reviewed and approved by the Ethics Committee of the Department of Sport and Exercise Sciences.

Many Thanks,

Alan Metcalfe

MRes Student

Department of Sport and Exercise Sciences

University of Bedfordshire

Bedford Campus

Polhill Avenue

Bedford

Tel: 01234 793264

Email: alan.metcalfe@beds.ac.uk

APPENDIX V. Study B testing consent from

Dear PARENT/GARDIAN

Over the next month at passport we will be asking the young athletes to assist in a research study looking at physical activity levels in young people. This is associated with completion of my Masters Degree at the University of Bedfordshire.

The study will collect data from young athletes in the Passport group such as:

- Height and Weight measured using tanita scales.
- Athletic performance measures recorded (from activities assessed during the passport training sessions)

Please be assured that all information and data collected will not identify an individual young athletes and all data be held securely at the University. The results of the study may be published but anonymity will be preserved.

The young athlete's participation in the project is entirely voluntary and he/she is free to withdraw from the project at any time without disadvantage or prejudice to their participation in Passport group activities. If you would prefer for your son / daughters data not to be part of the project then please inform either me or Jackie Cheshire (Bedford & County AC young athlete lead coach)

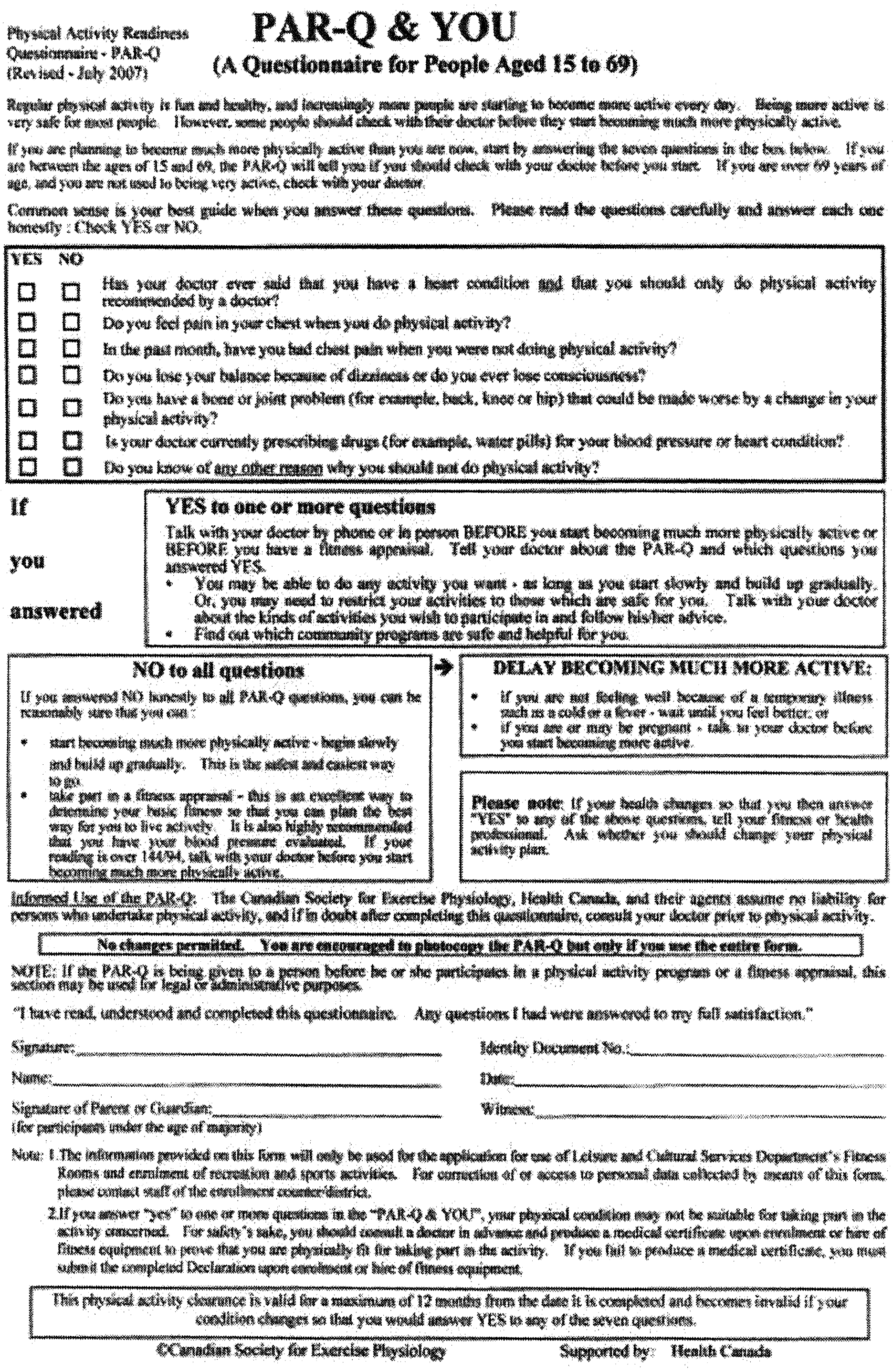
If you have any questions about the project please let me know.

Kind Regards,

Alan Metcalfe

Bedford & County Athletics Coach

APPENDIX VI PARQ



Physical Activity Readiness
Questionnaire - PAR-Q
(Revised - July 2007)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

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

YES	NO	
☐	☐	Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	Do you feel pain in your chest when you do physical activity?
☐	☐	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	Do you know of <u>any other reason</u> why you should not do physical activity?

If you answered

YES to one or more questions

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

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

NO to all questions

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

- start becoming much more physically active - begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal - this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

→ **DELAY BECOMING MUCH MORE ACTIVE:**

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

Please note: If your health changes so that you then answer "YES" to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

<u>Informed Use of the PAR-Q</u>: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

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

Signature:____________________ Identity Document No.:____________________

Name:____________________ Date:____________________

Signature of Parent or Guardian:____________________ Witness:____________________
(for participants under the age of majority)

Note: 1. The information provided on this form will only be used for the application for use of Leisure and Cultural Services Department's Fitness Rooms and enrolment of recreation and sports activities. For correction of or access to personal data collected by means of this form, please contact staff of the enrollment counter/district.

2. If you answer "yes" to one or more questions in the "PAR-Q & YOU", your physical condition may not be suitable for taking part in the activity concerned. For safety's sake, you should consult a doctor in advance and produce a medical certificate upon enrolment or hire of fitness equipment to prove that you are physically fit for taking part in the activity. If you fail to produce a medical certificate, you must submit the completed Declaration upon enrolment or hire of fitness equipment.

This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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APPENDIX VIII BLOOD QUESTIONAIRE

Please read the following:

a. Are you suffering from any known active, serious infection?

b. Have you had jaundice within the previous year?

c. Have you ever had any form of hepatitis?

d. Have you any reason to think you are HIV positive?

e. Have you ever been involved in intravenous drug use?

f. Are you a haemophiliac?

g. Is there any other reason you are aware of why taking blood might be hazardous to your health?

h. Is there any other reason you are aware of why taking your blood might be hazardous to the health of the technician?

Can you answer **Yes** to any of questions a-g? Please tick your response.

Yes ☐ No ☐

Small samples of your blood (from finger or earlobe) will be taken in the manner outlined to you by the qualified laboratory technician. All relevant safety procedures will be strictly adhered to during all testing procedures (as specified in the Risk Assessment document available for inspection in the laboratory).

I declare that this information is correct, and is for the sole purpose of giving the tester guidance as to my suitability for the test.

Name ....

Signed ....

Date ....

If there is any change in the circumstances outlined above, it is your responsibility to tell the person administering the test immediately.

The completed Medical Questionnaire (Par Q) and this Blood Sampling Form will be held in a locked filing cabinet in the School of PE and Sport Sciences laboratories at the University for a period of one-three years. After that time all documentation will be destroyed by shredding.

If you wish to have a photocopy of any of the completed documents, please ask for one.