The Effects of Varying Intensity Swimming and Kick Practice During a Warm Up on 200 m Freestyle Performance in Age Group Competitive Swimmers.

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i. Abstract

The aim of this study was to compare the effects of warm up at high (set at 90% of Maximal Aerobic Speed) and low (set at 70% of Maximal Aerobic Speed) intensity swimming, along with the inclusion and exclusion of isolated kick practice on 200 m freestyle swimming performance in Age Group swimmers (defined by British swimming as 11-14 years). This study was approved by the University of Gloucestershire's Research Ethics Committee. Seventeen competitive Age Group swimmers (n = 9 males, age 12 ± 1.22yrs, stature 1.58 ± 0.10m, mass 49.3 ± 9.75kg; n = 8 females, age 12 ± 0.99yrs, stature 1.58 ± 0.09m, mass 48.6 ± 7.79kg) performed four 200 m freestyle time trials on separate days after a specific warm up design, either low intensity without kick, low intensity with kick, high intensity without kick or high intensity with kick. All warm up protocols included five minutes land warm up activities focused on mobilisation and activation followed by two minutes of easy front crawl swimming. The warm up protocols then consisted of six minutes of either low intensity or high intensity front crawl swimming and two minutes of isolated front crawl kick; respective to the warm up design. All warm up protocols finished with two minutes of easy front crawl swimming and a five minute passive recovery period. The key findings of this study is that there was no statistically significant change in 200 m freestyle time trial results of Age Group swimmers in respect of total time or split times when manipulating intensity and kick variables during the warm up. The two-way repeat measures ANOVA test showed that there was no significant interaction effect between Intensity*Kick (P=0.171 - ETA^2 0.114), or main effect for Intensity (P=0.131 - ETA^2 0.137) and main effect for Kick (P value 0.692 - ETA^2 0.010). These results suggest that high intensity priming exercises associated with a speeding of $\dot{V}O_2$ kinetics has not improved performance which is in contrast to studies on 800 m running (Bailey *et al.* 2009). The results also suggest that swimming at a low intensity is sufficient enough to stimulate blood flow to the legs and increasing muscular temperature without isolated kick practices. This suggests that coaches may be correct in their current warm up protocols focusing on preparing for technical and tactical aspects of the event rather than physiological preparedness. Through examining the pacing strategies employed by 200 m freestyle swimmers, it would suggest that they do not reach their maximal workload until the final quarter of the event. This delay in maximal effort may allow the aerobic metabolism time to adjust to the exercise intensity thus diminishing the need for priming and a speeding of $\dot{V}O_2$ kinetics.

ii. Declaration Statement

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas.

Any views expressed in the thesis are those of the author and in no way represent those of the University.

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Chapter 1

Introduction

1.1 Introduction

British Swimming are focused on elite international swimming performance and provide world class talent programmes to identify, develop and monitor the next generation of emerging elite athletes (The ASA 2010). The first phase of the world class talent programme identifies 12 and 13 year olds that may have the potential to achieve future medal success on an international level. These 12 and 13 year old swimmers are selected based on the competitive times achieved at ASA Regional Championships. It is necessary for British Swimming to complete talent identification at Age Group level (aged 9-14 years) as swimming is an early specialisation sport where Youth athletes (aged 15-18 years) perform at the highest level (Swimming World 2016, British Swimming 2016). This method of selection does not take into account maturation or biological age and therefore late developing children are at a disadvantage. This method also contradicts Bayli and Hamilton's (2004) Long Term Athlete Development framework (LTAD) that British Swimming encourage swim coaches to employ (Lang and Light 2010). Due to the focus on competition that the world class talent programmes promote, many young swimmers could be neglecting key race skills needed to perform at an elite level or ignoring the LTAD framework in order to achieve short term success. Coaches try to produce a training programme which follows the LTAD framework but must also create strategies to maximise performance. Developing effective warm ups strategies may allow coaches to maximise performance whilst maintaining an alignment to the LTAD framework.

It is well documented that warm ups can enhance performance through the elevated core and muscular temperature related physiological alterations (Bailey *et al.* 2009, Bishop 2003, Boning *et al.* 1991, Chandler and Brown 2008, Marieb 2002, Romney and Nethery 1993).

Elevated core and muscular temperature induced by a warm up may increase cardiovascular, muscular and metabolic function and nerve conduction rate along with reducing risk of injury (Ozyener *et al.* 2001, Sargeant 1987, Seto *et al.* 2005, Yaicharoen *et al.* 2012). Whilst studies state that a warm up will improve the maximum and mean propelling force in front crawl (Neiva *et al.* 2011, Neiva *et al.* 2013, Zochowski *et al*. 2007); these studies did not detail the structure, content or duration of the warm up. Without scientific literature to direct them, swim coaches are offered conflicting opinions by coaching manuals with some suggesting brief, low intensity warm ups (Colwin 2002, Wright and Copland 2004) with others suggesting longer, higher intensity warm ups (Brooks 2011, Salo and Riewald 2008). A lack of properly controlled swimming trials has lead coaches to make their own warm up protocols based on trial and error rather than scientific research. Swim coaches commonly apply a low intensity warm up as it is traditionally thought that this would save energy for the race by maintaining glycogen stores and limiting the risk of fatigue through the build-up of lactic acid associated with a higher intensity warm up. These warm ups seem to be based completely on mobilisation of joints and performing skills with best technique, without consideration for physiological responses needed to enhance performance (Figueiredo *et al*. 2013).

Both 200 m freestyle swimming and 800 m running performance are maximal effort exercise bouts lasting around two minutes. The energy cost of propulsion in 200 m freestyle swimming is high, comparable to that of 800 m running, and front crawl swimming speed is thought to be correlated with maximum volume of oxygen uptake ($\dot{V}O_{2max}$) (Lavoie and Montpetit 1986) as is 800 m running (Thomas *et al*. 2005). High intensity priming exercises in the warm up have been reported to make significant improvements in 800 m running

(Bailey *et al*. 2009, Bailey *et al*. 2016, Ingham *et al*. 2013, Jones *et al*. 2003). To date there has been no systematic investigation of the effects of warm up intensity in 200 m swimming.

$\dot{V}O_{2max}$ is only one of the physiological factors that has an influence on 200 m freestyle performance. Other factors include time course of $\dot{V}O_2$ response ($\dot{V}O_2$ kinetics), amount of adenosine triphosphate (ATP) generated by anaerobic metabolism (anaerobic capacity (Green and Dawson 1993)), muscle power (strength and speed of muscle contraction) and flexibility. There are mechanical factors that influence performance as well; stroke length, stroke frequency, kick pattern, start and turning ability and breathing pattern (Toussaint and Beek 1992). The start and turn are important sections of the race that can have a significant influence on the performance outcome. Starts and turns are primarily affected by muscle power and therefore an intervention that can enhance muscle such as post-activation potentiation could enhance performance. Post-activation potentiation can enhance the power output of speed-strength performance due to a heavy load strength exercise preceding it (Gamble 2013). In essence, the post-activation potentiation effect allows a greater number of attachment sites within the individual muscle fibres; this greater connectivity within the individual muscle fibres allows a stronger force of contraction which is then amplified throughout the entire muscle. While post-activation potentiation could have a significant influence on performance, the current study will be focusing on the influence of $\dot{V}O_{2max}$ and $\dot{V}O_2$ kinetics, in line with their current training programme and guidelines set out by British Swimming and the Long-Term Athlete Development pathway.

During a 200 m freestyle race, a strong six beat leg kick pattern is required for optimal performance (Sortwell 2011); therefore ensuring an elevated muscular temperature in the legs is a key priority for the warm up. It is not conventional for swim coaches to include isolated kick practices (without the use of arms) during the warm up (Colwin 2002, Brooks 2011, Salo and Riewald 2008, Wright and Copland 2004). Whilst the kick pattern during the race will have limited direct propulsion, it indirectly has an impact on maximal swimming speed by reducing drag and increasing stroke length at a higher stroke frequency (Gatta *et al*. 2012, Sortwell 2011). Coaches are aware of the importance of the kick during the race which, rather than ensuring that the legs are sufficiently primed and ready to work at maximum intensity, often leads coaches to fear including kick practice in the warm up. General belief is that including isolated kick exercises will result in lactic acid accumulation, decreased muscle power output and impaired performance associated with skeletal muscle fatigue (Cairns 2006) in the legs. Conversely integrating an isolated kick exercise into the warm up would encourage a greater amount of blood flow to the large muscle groups that perform the kick action and thus could potentially prepare them better for the subsequent performance. To date there has been no systematic investigation of the effects of the use of lower limb during the warm up on 200 m swimming.

1.2 Research Questions and Research Objectives

The aim of the study was to understand if improvements in swim performance through manipulating the warm up procedures can be evidenced. The study will examine the effects of high and low intensity exercise bouts along with the inclusion and exclusion of isolated kick practices on subsequent swimming performance in competitive age group swimmers between 11 and 14 years.

This study has two research questions:

1. Does the intensity of the warm up effect 200 m freestyle swim performance?
2. Does the inclusion of kick practices in the warm up effect 200 m freestyle swim performance?

This study has two research objectives:

1. To compare the effects of high and low intensity warm ups on 200 m freestyle swim performance.
2. To compare the effect of warm ups that include and exclude an isolated kick practice on 200 m freestyle swim performance.

Chapter 2

Literature Review

2.1 British Swimming

British Swimming is a section within the Amateur Swimming Association responsible for governing elite swimming, water polo and synchronised swimming. Their primary aim is to achieve medal success for Great Britain in major championships (primarily the Olympic and Paralympic Games) (Lang and Light 2010). Competitive swimming is split into three age bands; Age Group refers to athletes aged between 9 and 14 years, Youth is athletes between 15 and 18 years and Senior is athletes over 18 years (The ASA 2010). Athletes compete in a range of events covering distances of 50 m up to 10 km across four different swimming styles; front crawl, backstroke, breaststroke, and butterfly, along with an individual medley that incorporates all four styles into one event (Pyne *et al*. 2001). In order to monitor and develop international level athletes, British Swimming runs the World Class Programme which at 'Level 1' identifies young swimmers who may have the potential to win Olympic medals. These programmes provide emerging athletes with wider recognition in the sport and access to further sport science support, including in depth sport psychology, nutrition, physiotherapy, flume technical analysis and strength and conditioning programmes, which most clubs are unable to provide. These opportunities for Age Group swimmers enhance their chance of successful competitive results and remaining on the Elite Performance Pathway as a Senior swimmer. To be selected for the Level 1 programme, swimmers must have competitive results ranking them in the top 24 swimmers in their region at age 12-13 years (The ASA 2010).

The selection criteria used by British Swimming conflicts with academic research and established Long Term Athlete Development (LTAD) framework (Bayli and Hamilton 2004). The LTAD states that athletes at Age Group level should be focused primarily on training and developing their $\dot{V}O_{2max}$ rather than on competition (Ford *et al*. 2011). Coaches are encouraged to follow the LTAD plan by British Swimming and therefore Age Group athletes should follow a training programme that stimulates development of their $\dot{V}O_{2max}$ (Lang and Light 2010). Age Group athletes that follow the British Swimming recommended training programme by predominately training $\dot{V}O_{2max}$ could potentially neglect key race skills that are needed to perform at an elite level and be selected for British Swimming Talent Programmes (Gulbin *et al*. 2013). Swimming is an early specialisation sport and Youth swimmers perform at the highest level, demonstrated by a 15 year old winning the gold medal in the women 100 m breaststroke at the London 2012 Olympic games and at 16 years old breaking the world record in 50 m and 100 m breaststroke at the 2013 World Championships (Swimming World 2016). It is therefore necessary for talent to be identified at Age Group level, however the selection criteria uses chronological age without consideration for growth or maturation (Ford *et al*. 2011).

Children develop through maturation at differing rates; therefore children of the same chronological age have differing physical characteristics such as height, weight and somatotype (Iuliano-Burns *et al*. 2001, Malina *et al*. 2006, Malina and Geithner 2011). The largest variations in physical characteristics are seen around the adolescent growth spurt (Mirwald *et al*. 2002). Physical stature has been shown to influence swimming performance in Senior athletes (Grimston and Hay 1986) and studies on children have shown maturity related difference in speed, strength and stamina tests (Katzmarzyka *et al*. 1997), however the present author is unaware of any studies on swimming performance of children. Changes in body size, composition and physiological factors (i.e. $\dot{V}O_{2max}$, speed and muscular strength and power) that occur with puberty and the growth spurt are well documented (Baxter-Jones *et al*. 1993). Within a chronological age group, children who are advanced in sexual and skeletal maturity perform, on average, better in strength, power and speed tasks compared to children who are later in sexual and skeletal maturity (Malina 1994). Malina *et al*.'s (2004) study supports the LTAD and concludes that training can be a significant contributor to $\dot{V}O_{2max}$ for Age Group athletes, whereas sexual and skeletal maturities are significant contributors to speed and muscular strength and power; justifying that their training should be focused on development of their $\dot{V}O_{2max}$. Early maturing athletes have a distinct advantage in Age Group competitions and therefore more chance of being selected for British Swimming Talent Programmes. However these early maturing athletes that display the desired performance at Age Group level will not necessarily retain these attributes throughout maturation (Ackland and Bloomfield 1996). With the influence that growth and maturation has on Age Group performance (Mirwald *et al*. 2002), it could be considered unfair to use chronological age as selection criteria at this stage of young athletes' development and may misinterpret an athlete's potential. Many studies have tried to use biological age to separate groups within a sample population of maturing participants. Biological age is often discussed in terms of maturational timing around a specific maturational event such as peak height velocity. Peak height velocity is defined as maximum velocity in growth during adolescence (Philippaerts *et al.* 2006) Maturity offset indicates time before or after peak height velocity in years using chronological age, height, weight, sitting height and leg length (Malina *et al*. 2006). Coaches try to produce a training programme which follow the LTAD framework but also must create strategies to maximise performance of both early and late maturing athletes; of which warm ups should be considered.

The present study considers how using warm up interventions could enhance 200 m freestyle performance in Age Group swimmers. 200 m freestyle has been selected as it aligns to the requirements for Age Group competition set out by British Swimming (The ASA 2010)

2.2 Considerations for Measurements in Water

During a performance swim, there are many psychological and tactical decisions that need to be made during the race including; the start, number of underwater fly kicks during the transition up to stroke, judging the distance in to the turn and changing the stroke pattern to put the swimmer into the correct position for the turn, executing the turn and judging the finish. With so many factors that can influence performance, it may be hard to distinguish between physiological preparedness and having made all these decisions correctly. The current study aims to measure the impact of physiological variables. In order to isolate these physiological factors, many parts of a standard competition warm up have been removed as they may have an impact on the results. Therefore these warm up protocols will not include any psychological or tactical preparation. The selected participants for the current study compete in twelve competitions each year, racing multiple events during each competition with a minimum of two years' racing experience. This would suggest that the participants are at least familiar in making these decisions during a performance swim and any psychological or tactical factors should have limited impact on the results, however any obvious psychological or tactical errors during the performance test will be noted.

Physical activity performed at different intensities produce different physiological responses. In order to understand the affect intensity has on performance, it must be quantified and prescribed as either an internal or external workload. In order to approach this question scientifically, and therefore be able to draw meaningful and reproducible conclusions, intensity will be quantified using an objective measure.

2.2.1 $\dot{V}O_{2max}$ Assessment

The most accurate and reliable method of assessing an athlete's cardio-respiratory fitness and maximal capacity for exercise is the direct measurement of an athlete's $\dot{V}O_{2max}$ (Wallace *et al*. 2014). This provides the maximal end of the intensity continuum and allows for intensity to be quantified in term of a percentage of an athlete's $\dot{V}O_{2max}$. Kavcic *et al*. (2012) define $\dot{V}O_{2max}$ as the highest rate of oxygen consumption and utilisation during exercise. Unfortunately, obtaining direct measures of $\dot{V}O_{2max}$ in the field are very impractical as they require not only specialist equipment and a controlled environment but a number of operators with specific knowledge to interpret the results (Wallace *et al*. 2014). Also only one participant can be tested at time making it very time consuming to test a larger sample size associated with field testing. These tests can only be performed using a treadmill or ergometer and therefore lack the specificity for many sports (Czuba *et al*. 2010). Specifically for swimmers, these exercises focus predominately on the lower body to carry the workload; this is in contrast to their normal workload profile which is normally carried by the upper body. Swimmers may need to use different methods to quantify exercise intensity as these methods may underestimate $\dot{V}O_{2max}$ due to a lack of sport specificity. Whilst $\dot{V}O_{2max}$ testing may not be appropriate for studies on swimmers, the understanding of $\dot{V}O_{2max}$ has lead to the validation of other techniques for quantifying exercise intensity.

2.2.2 Blood Lactate Testing

Intensity can be quantified into three specific zones using blood lactate concentrations; low lactate zone, lactate accommodation zone (where blood lactate concentration is elevated but production and removal establish an equilibrium), and the lactate accumulation zone (where the production of blood lactate exceeds maximum removal) (Seiler and Kjerland 2006). In Seiler and Kjerland's (2006) study on twelve male cross country skiers, these training zones were quantified in terms of blood lactate concentration reference points; Zone 1 less than 2.0 mM, Zone 2 between 2.0 mM and 4.0 mM and Zone 3 greater than 4.0 mM. Using portable lactate analysers, one is able to measure blood lactate concentrations with a single 20 µl blood sample during training sessions to ensure that athletes are training at the correct internal training load with relative ease (Maughan *et al*. 2007).

Capillary sampling from fingertips is generally used for safety and ease. Differences in blood lactate values will occur according to the form of blood used: venous, arterial or capillary; part of blood used: whole, plasma or serum; the sampling site; post sampling treatment and analysis method. All subjects must adopt identical procedures for every sample in order for them to be comparable. This method is more practical in the field as the test protocol can be adapted to make it more sport specific. Blood samples can be taken relatively quickly allowing for testing of more than one participant at a time, and can all be completed by one researcher. Whilst the equipment needed is specialist, it is also small and portable adding the easy of testing in the field. Blood sampling is an invasive procedure, however it is relatively painless and a small amount of blood is taken as a sample. Analysing blood by using portable lactate analysers can provide results in 60 seconds; this makes it a very useful and quick method for quantifying exercise intensity during training. With feedback readily available, training intensity can be adjusted to ensure athletes are getting the correct internal training load. Specialist training is required to be able to take blood samples, making it impractical for many coaches to apply this method. This method would be appropriate for studies on swimmers, as it can be made sports specific, can be carried out in a swimming pool environment and, when used appropriately, can provide a very accurate measure of exercise intensity.

A fixed blood lactate reference point of 4 mM is widely accepted as the value to monitor and assess endurance performance in adult athletes (Jacobs 1986, Seiler and Kjerland 2006). The 4 mM value correlates to the point at which equilibrium between lactate production and removal is reached. However this may not be the case for children. Tolfrey and Armstrong (1995) and Beneke *et al.* (2005) both have shown children to reach lower peak blood lactate values even though they are working at their maximal intensity. Tolfrey and Armstrong's (1995) study showed that peak lactate increased through maturation. They measured peak blood lactate from prepubescent and teenage boys, and adult men reporting values of 4.5 mM, 5.8 mM and 8.7 mM respectively. Their study suggests that 2.5 mM in prepubescent and teenage boys may be equivalent to the 4 mM reference point in adults. However this study was only conducted on males and does not provide any evidence for peak lactate changes in females through maturation. Also this study does not detail how maturation is assessed and what marks the transition between teenage and adult. The results of their study showed that prepubescent and teenage boys are able to exercise at close to $\dot{V}O_{2max}$ without accumulating high levels of blood lactate, however without more information on their maturation assessment it is difficult to replicate. Tolfrey and Armstrong (1995) do not provide a definitive explanation as to why there are differences between child and adult blood lactate concentrations. Speculative suggestions include that children have lower muscle lactic acid production (Eriksson *et al.* 1971), that children's adrenaline response to exercise, which can initiate metabolic process including lactic acid production, is different to adults (Macek 1986), or that children have an enhanced ability to produce energy aerobically (Berg *et al.* 1986). All of these speculative suggestions lack the physiological evidence to be supported, and as such the understanding of why children appear to produce lower blood lactate values is still incomplete.

Williams and Armstrong (1991) failed to identify any differences in peak blood lactate values across maturation. Whilst Beneke *et al.*'s (2005) study showed an increase in peak blood lactate across maturation, boys 8.6 mM, adolescent 12.0 mM and adult 12.7 mM, the peak blood lactate value for boys is comparable to the adult peak lactate value from Tolfrey and Armstrong's (1995) study. Beneke *et al.* (2005) suggest that there is not a physiological or metabolic difference between children and adults but rather the blood lactate kinetics do not appear to respond at the same rate in children compared to adults. They suggest that children are able to produce high levels of blood lactate; it just takes more time to for these values to be displayed in their blood. Without a complete understanding of why children appear to produce lower peak blood lactate values or how long after exercise their higher values will be present, a pilot study should be conducted to ascertain if blood lactate is a viable option for the determination of exercise intensity test.

2.2.3 Heart Rate Monitoring

Seiler and Kjerland (2006) suggest that heart rate is the practical link between laboratory test measures and quantification of exercise intensity. Heart rate monitors are more readily accessible than portable lactate analyzers. For many sports, intensity is normally quantified, monitored and controlled with heart rate monitoring techniques, due to the ease of measuring this data (Algrey *et al*. 2011). This is supported by Wallace *et al*. (2014) who state that the most commonly used method for quantifying internal training loads is heart rate monitoring as a measure of exercise intensity. Heart rate offers an alternative that is easily measured but also appears to maintain its close relationship to $\dot{V}O_{2max}$ and blood lactate concentration during land based exercises. Algrey *et al*. (2011) state that the heart rates associated with ventilatory thresholds remain quite stable for prolonged periods, which means that once the heart rate for the first and second ventilatory threshold have been established, only drastic changes in aerobic fitness may cause a different heart rate to be associated to a particular ventilatory threshold. The first ventilatory threshold, known as the aerobic threshold, marks an increase in the level of oxygen inside the lungs without an increase in the level of carbon dioxide, the second ventilatory threshold, known as the anaerobic threshold, marks the increase of carbon dioxide inside the lungs. This is supported by Rodri´Guez-Marroyo *et al*. (2012) who justifies heart rate as a reliable measure to quantify exercise intensity. Also heart rate can be monitored during any exercise activity; allowing tests to be sport specific, using large sample sizes and can be conducted in any environment making it ideal for field testing. In relation to studies on swimmers, Lupo *et al*. (2014) state that heart rate reductions occur when the body is immersed in water, therefore quantifying exercise intensity through heart rate could underestimate the intensity. Other methods of objective physiological measures to quantify exercise intensity should be used as an alternative during aquatic sports. Aquatic heart rate monitors are very expensive and have not been validated against $\dot{V}O_{2max}$ or blood lactate methods. For these reasons, heart rate monitoring methods are less appropriate for studies on swimmers.

2.2.4 Maximal Aerobic Speed Assessment

Under laboratory conditions the assessment of $\dot{V}O_{2max}$ can provide information relating to specific physiological states such as velocity at lactate or ventilatory thresholds and velocity at $\dot{V}O_{2max}$ (Billat 2001). Velocity at $\dot{V}O_{2max}$ (v $\dot{V}O_{2max}$) is the slowest possible speed required to produce a $\dot{V}O_{2max}$ response and is also known as maximal aerobic speed (MAS) (Di Prampero *et al*. 1986, Lacour *et al*. 1991). By focusing on the velocity rather than the physiological response, individual workloads can be prescribed and monitored more easily along with being better understood by the participants as target times and pacing strategies are very common in their regular training programme. There are many field based tests that can be used to provide an indirect measure of $\dot{V}O_{2max}$ and subsequently provide the MAS. Test selection is an important consideration as an intermittent or incremental test design. Many require a greater input from the anaerobic energy system and therefore will not provide a true measure of MAS. A continuous linear test such as the traditional 12 minute Cooper Run is a commonly used method for assessing the aerobic function of dry land sports. The Cooper Run requires athletes to cover the furthest distance they can within 12 minutes (Cooper 1968). MAS is then calculated as distance covered divided by time and reported as metres per second. Chamoux *et al*. (1996) state that the time required to stress the aerobic system and measure MAS is four minutes 58 seconds therefore a five minute time trial would be a sufficient duration to test MAS. Berthon *et al*. (1997) support this by reporting significant correlations between v $\dot{V}O_{2max}$ and average velocity during a five minute trial. A five minute time trial test can easily applied across different modes of exercise and would be an appropriate method for swimming (Barker 2011). The aim is to cover the maximum distance possible in five minutes. The distance covered measured to the nearest metre is divided by the time in seconds to give 100% of maximal aerobic speed (MAS) in the form of metres per second. Please see Eq1 for example workings.

$$(Eq1)\ MAS = 400\ m / 300\ s = 1.33\ m.s^{-1}$$

Using this equation, the researcher was able to set individual external workloads of low intensity and high intensity. Intensity was set using a percentage of MAS during the warm up tests. Mitchell and Huston (1993) state that 70% of MAS corresponds to low intensity (LI). High intensity (HI) was set at 90% of MAS as this falls within the guidelines set by Sylta *et al*. (2014). These percentages for MAS were calculated into 50 m split times so that the participants could swim at the required workload. Please see Eq2 and Eq3 for example workings.

$$(Eq2)\ LI = 1.33\ m.s^{-1} / 100 \times 70 = 0.931\ m.s^{-1}$$

$$50\ m / 0.931\ m.s^{-1} = 53.70\ s\ per\ 50\ m\ split$$

$$(Eq3)\ HI = 1.33\ m.s^{-1} / 100 \times 90 = 1.197\ m.s^{-1}$$

$$50\ m / 1.197\ m.s^{-1} = 41.77\ s\ per\ 50\ m\ split$$

2.3 200 m Freestyle Swimming

In order to understand how to correctly prescribe an effective competition warm up for swimming, one must examine the mechanical and physiological factors that can limit performance. The qualifying time for the 200 m freestyle race at the 2015 ASA South-West

Regional Championships for 14 years boys was 2.12.23 and for girls was 2.16.19 (see Appendix A). Age Group swimmers are required to swim a single maximum effort performance under the corresponding time. The mechanical factors that influence performance include stroke length, stroke frequency, kick pattern, start and turning ability and breathing pattern (Toussaint and Beek 1992). The swimmers need to perform explosive leg actions when diving off the blocks for the start and pushing off walls during turns (Breed and Young 2002). The mechanics of the stroke force swimmers into a restrictive breathing pattern. In order to maintain efficiency, breaths must be taken at set intervals within the stroke cycles. There are prolonged periods underwater during transitional phases between the start or turn and the stroke in which swimmers hold their arms in an extended streamline position and perform multiple fly kicks using a simultaneous leg action (Cohen *et al*. 2011). These mechanical factors therefore have an influence on the physiological factors. Physiological factors include maximum volume of oxygen uptake ($\dot{V}O_{2max}$), time course of $\dot{V}O_2$ response ($\dot{V}O_2$ kinetics), amount of adenosine triphosphate (ATP) generated by anaerobic metabolism (anaerobic capacity (Green and Dawson 1993)), muscle power (strength and speed of muscle contraction) and flexibility (Smith *et al*. 2002).

2.4 Mechanical Factors Affecting 200 m Freestyle Performance

2.4.1 Freestyle Arm Action

Basic freestyle stroke parameters involve a prone flat body position with longitudinal rotation to minimise resistance and continuous and alternating arm and leg actions generate the force required for propulsion. There are many variations on the front crawl arm stroke technique. Zatoń *et al*. (2012) examined three variations: a standard arm pull where the hand trajectory in the frontal plane resembles the letter ‘S’ during the propulsive phase and the arms maintain equal time intervals during the propulsive and recovery phases; a kayaking arm pull variant where the hand trajectory in the frontal plan resembles the letter 'I' and the arm movements are performed in uninterrupted coordination similar to the standard arm pull, but allows for an increased stroke frequency. Finally, a loping arm pull variant where the hand trajectory in the frontal plan resembles the letter 'I' however the arm movements are performed with unequal time intervals during the propulsive and recovery phases. At the end of the recovery phase once the hand has entered the water, the hand is held in place for a slightly extended period of time, creating an impression of one arm catching up to the other allowing for an increased stroke length but decreased stroke frequency. The results suggest that the kayaking and loping arm pull variants might appear to be more effective and efficient than the standard arm pull technique and could contribute to lower energy expenditure and an increased velocity. However Zatoń *et al*. (2012) state that the results do not offer a universal solution regarding which technique enhanced performance, but identified a need for individualised technique training that should manipulate stroke length and stroke frequency to ensure their technique is efficient and effective and suited to the demands of the event distance. The relationship between technique and performance is more apparent in swimming than in other sports due to the need to propel oneself through water (Seifert *et al*. 2004). An efficient and effective technique in swimming will enhance propulsion and reduce frontal and longitudinal resistance along with resistance caused by eddy currents (Sortwell 2011). As water does not provide a stable platform from which generate power, there are variations in the force generated and the velocity achieved in each arm stroke. This variable velocity, combined with water resistance, results in increased energy expenditure in order to maintain speed (Zatoń *et al*. 2012) than comparable dry land activities. Stroke length, stroke frequency and kick pattern are all major determinants of front crawl swimming speed (Chollet *et al*. 2000). Long efficient arm strokes performed with a high stroke frequency and a continuous kick are needed for optimal swimming performance (Sortwell 2011). Efficient and effective swimming technique is therefore defined as increasing the velocity of the athlete whilst reducing the variations in velocity of each arm stroke (Kolmogorov and Duplischeva 1992). The relationship between stroke length and stroke frequency is the main variable for maintaining stroke efficiency and effectiveness, however this relationship is correlated to the distance of the event. Short distance events (50 m, 100 m) often observe a shorter stroke length combined with a higher stroke frequency whereas long distance events (800 m, 1500 m) observe a longer stroke length with a lower stroke frequency (Seifert *et al*. 2004) and middle distance events (200 m, 400 m) attempt to find a balance between length and frequency.

2.4.2 Freestyle Kick Action

Whilst the kick has limited direct propulsion, it indirectly has a significant impact on maximal swimming speed. Kick plays a vital role in balancing and stabilising the trunk improving buoyancy and longitudinal rotation (Gatta *et al*. 2012). As the body longitudinally rotates through to each side, the kick prevents the lower limbs from lateral deviation of the hips. The kick also improves the effectiveness of the upper body propulsion by elevating the lower limbs, caused by the continuous downward pressure under the feet (Sortwell 2011). This elevation reduces the frontal resistance bringing the body line to a flat, horizontal position and also reduces the impact of eddy currents. Eddy currents are formed by the swell of water forming behind an object as it travels through the water, pulling much of the water along with the object in its wake. The impact of eddy currents is primarily affected by the size profile of the object. Swimming with the legs lower in the water will create a larger profile in the water and increase the impact of eddy currents, whereas elevating the legs will reduce the profile of the body line and reduce the impact of eddy currents. The kick pattern has a positive correlation to stroke length (Sanders & Psycharakis 2008); therefore a six beat kick (six kicks for two complete arm strokes) contributes to the overall efficiency of the stroke. A six beat kick is necessary to maintain stroke length whilst increasing stroke frequency and subsequently increasing swimming speed (Sortwell 2011). At maximal swimming speed, a six beat kick provides a more stable body position and therefore will reduce the negative effects that variations in velocity of each arm stroke have on overall swimming speed. Sprint and middle distance events often use a six beat kick whereas longer distance events often use a two or four beat kick (Toussaint and Beek 1992). A two or four beat leg kick will be less effective in elevating the lower limbs and balancing the longitudinal rotation, causing an increased frontal resistance, eddy currents and lateral deviation compared to a six beat leg kick. Performing a six beat leg kick can enhance propulsion up to 10% when swimming at maximum velocity (Gatta *et al*. 2012). Whilst kick may not significantly increase maximal swimming speed through enhancing the force generated during the stroke, kick is able to significantly increase maximal swimming speed by reducing the amount of resistance caused. Sleivert and Wenger (1993) study suggests that the key physiological variables that influence swimming performance in Senior athletes are $\dot{V}O_{2max}$, ventilatory threshold and absolute leg flexion strength. Maximal swimming speed with efficient and effective stroke mechanics relies heavily on the kick pattern therefore it may be necessary to include activities in the warm up that target the kick muscle groups. Although the effect of kick on maximal swimming speed is well understood, to date there have been no systematic investigations into the effects of warming up the leg muscles through isolated kick practices on swimming performance.

2.4.3 Starts, Turns and Transitions

Starts, turns and the transitional underwater phases (following the start and turns) can have a significant influence on performance (Miller *et al*. 1984), and many elite international race results are decided during these sections of the race (Blanksby *et al*. 2002). Guimaraes and Hay (1985) state that to produce a fast entry, the take off velocity must be high and the athlete needs to be in a streamlined position whilst in flight in order to minimise the reduction in velocity on entry into the water. The primary components influencing the effectiveness of the start are reaction time, leg power and resistance upon entering the water or streamlining (Breed and Young 2002). Webster *et al*. (2011) suggest that during the 200 m freestyle event, 21% of the overall race time can be attributed to the turn (time taken from 5 m into and 10 m out from the wall). The preferred method for turning in freestyle is the tumble turn. Swimmers rotate around the horizontal axis to push off the wall in a streamlined position and initiate the underwater fly kick to minimise deceleration. The first stroke cycle should be performed before the swimmer's velocity drops below their swimming speed (Clothier *et al*. 2000). If swimmers allow their velocity to drop before they have started their first cycle, they will have to accelerate again which has been linked to an increase in energy expenditure which can have a negative impact on performance (Webster *et al*. 2011). The primary components influencing turn and transition speed are agility, leg power and streamlining (Breed and Young 2002). Effective starts, turns and transitions rely on leg power, therefore it may be necessary to include activities in the warm up that target the leg muscle groups.

2.5 Physiological Factors Affecting 200 m Freestyle Performance

As swimming takes place in an aquatic environment, it presents different resistive and drag forces, respiratory conditions and temperature stresses compared to air (Holmer 1992). The energy cost of propulsion in 200 m freestyle swimming is high, comparable to that of 800 m running. Front crawl swimming speed is thought to be correlated with $\dot{V}O_{2max}$ and $\dot{V}O_2$ kinetics (Lavoie and Montpetit 1986). The energy cost differs for each stroke technique; the lowest is front crawl, followed by backstroke, then butterfly and breaststroke are significantly higher. The rate of energy expenditure is related to speed, propelling efficiency and resistance (Toussaint and Hollander 1994).

2.5.1 Cardiovascular Factors

Holmer *et al*. (1974) suggest that cardiac output (the volume of blood pumped by the heart per minute) for swimmers may not be a limiting factor on performance since they have been shown to achieve values 8-10% higher during running based tests when compared to swimming based test. The observed lower cardiac output value for swimming could be attributed to a drop in maximal heart rate by 10-15 beats per minute whilst swimming compared to running (Magel 1971). Holmer (1992) suggests that this lower maximal heart rate can be explained by improved diastolic filling of the heart when the body is in a horizontal position with minimal gravitational resistance. Peripheral blood pressure appears to be higher in swimming than running and may suggest that whilst heart rate and cardiac output are not reaching their maximal values, the heart may be working at its maximal limit for that mode of exercise, thus representing an upper limit to performance (Holmer 1992). Other cardiovascular factors, such as capillary density and metabolic capacity of active muscles also influence oxygen delivery and utilisation. These factors are therefore important determinants of $\dot{V}O_{2max}$.

2.5.2 $\dot{V}O_2$ Kinetics

$\dot{V}O_2$ kinetics is defined as the rate of response of oxygen uptake following the start of exercise, and describes the rate at which the cardiovascular system is able to supply oxygen to the working muscles (Perrey 2010). Oxygen uptake has a linear relationship to intensity. At low and moderate exercise intensity (up to 70% of $\dot{V}O_{2max}$ (Zochowski *et al*. 2007)), the exponential increase in pulmonary oxygen uptake can be characterized as a single time constant, including a delay which reflects the tissue-to-lung vascular transit delay, to produce a steady state where the body is able to produce enough oxygen to meet demand (Whipp *et al*. 1982). This process is termed the primary component of $\dot{V}O_2$ kinetics. There is a lag between the start of exercise and oxygen consumption reaching the steady state. During the initial period of exercise, the ATP demand cannot be met by oxygen consumption and therefore ATP re-synthesis occurs anaerobically in order to meet the required exercise intensity, a difference which is termed the oxygen deficit (Burnley *et al*. 2000). At high (above 70% $\dot{V}O_{2max}$) or severe (close to or at $\dot{V}O_{2max}$) intensity exercise, $\dot{V}O_2$ kinetics responds with the primary component; the amplitude is greater in an attempt to reach a steady state. However, after the oxygen consumption plateaus, there is another more gradual rise elevating the level of oxygen consumption above that of the originally predicted steady state. This second rise is termed the slow component (Whipp 1994). The slow component appears to be correlated with muscle fatigue and reflects a decreasing muscle efficiency as a progressively greater energy demand is required for the same muscle workload (Rossiter *et al*. 2002). In Burnley *et al*'s. (2001) study they reported that a six minute high intensity priming exercise bout reduced the amplitude of the slow component by ~160 ml min^{-1} during a second six minute high intensity exercise bout. Whilst performance in a 200 m freestyle event may not be long enough to be influenced by the slow component, factors that enhance the amplitude of the primary component might improve exercise tolerance and improve performance. Enhancing the amplitude of the primary component of $\dot{V}O_2$ kinetics should be of consideration for the warm up.

Once exercise stops, there is a significant drop in oxygen consumption; however it does remain slightly elevated for some time before returning to the base level of resting oxygen consumption. This is termed excess post-exercise oxygen consumption (EPOC). During this period, the elevated oxygen consumption primarily assists in the re-synthesis of ATP and phosphocreatine (PCr) along with restoring the myoglobin oxygen stores. Burnley *et al*. (2001) studied the effect of recovery time following six minutes of high intensity exercise. The authors' results show that after six minutes of recovery, baseline $\dot{V}O_2$ was increased by ~120 ml min^{-1} prior to the onset of a second six minute bout of high intensity exercise, in contrast to the 12 minute recovery period that allowed $\dot{V}O_2$ to return to pre-exercise baseline levels prior to the onset of the second heavy exercise bout. Volek (2001) however reported that 95% of phosphocreatine stores can be replenished within four minutes of passive recovery, therefore the elevated baseline of $\dot{V}O_2$ between four and six minutes after high intensity exercise could be used to enhance a subsequent swimming performance.

Sousa *et al*.'s (2011) study on ten Senior male 200 m freestyle swimmers observed that $\dot{V}O_{2max}$ and the amplitude of the primary component of $\dot{V}O_2$ kinetics are directly correlated to average speed during the first 50 m and the overall 200 m performance. *Sousa et al.* (2011) state that aerobic metabolism accounted for 78.6% of the energy contribution during the 200 m freestyle performance. Figueiredo *et al*. (2011) found similar results across ten Senior male 200 m freestyle swimmers. The 200 m swim performance was divided into 50 m lap splits and reported aerobic metabolic contributions as 44.6%, 73.2%, 83.3% and 66.6% for each consecutive lap, respectively. During the first and final lap in particular, the anaerobic metabolism is highly stimulated causing a high level of blood lactate concentration and subsequently impacting the level of fatigue and exercise tolerance (Figueiredo *et al*. 2013). Fatigue not only limits the amount of force being produced from each arm stroke but will also shorten stroke length and lower stroke frequency, causing a decrease in velocity and a rise in velocity variation thus impairing the efficiency and effectiveness of the stroke mechanics. Increasing the rate of response and the amplitude of the primary component of $\dot{V}O_2$ kinetics will reduce the contribution of the anaerobic metabolism during the first 50 m lap and subsequently reduce fatigue and increase exercise tolerance. Similar results were reported on Youth 200 m breaststroke swimmers (Strzala *et al*.'s 2015) and Senior 100 m freestyle swimmers (Lätt *et al*. 2010). Whilst energy is generated by both aerobic and anaerobic processes, $\dot{V}O_{2max}$ and $\dot{V}O_2$ kinetics have a significant influence on performance.

According to Bayli and Hamilton's (2004) LTAD model, Age Group athletes are unable to make significant improvements to their anaerobic capacity and should focus their training at this stage on developing their $\dot{V}O_{2Max}$; a theory that is supported by studies in maturation (Katzmarzyka *et al*. 1997, Malina 2004, Mirwald *et al*. 2002). Baxter-Jones *et al*. (1993) state that correct training stimulus can improve $\dot{V}O_{2max}$ in prepubescent children. This would suggest that the training stimulus that can affect Age Group 200 m freestyle performance would be $\dot{V}O_{2max}$ (Ford *et al*. 2011) and therefore would be comparable to the energy requirements of Youth and Senior athletes, These studies (Bayli and Hamilton 2004, Figueiredo *et al*. 2013, Ford *et al*. 2011, Lätt *et al*. 2010, Sousa *et al*. 2011, Strzala *et al*.'s 2015) suggest $\dot{V}O_2$ kinetics has a significant impact on 200 m freestyle performance for Age Group, Youth and Senior swimmers.

The process of transporting oxygen involves a higher workload for swimmers compared to other athletes. Swimmers are exposed to hydrostatic pressure around the chest, prolonged expiration into water, restrictive breathing patterns that alter alveolar gas diffusion, and repeated expansion of the lung to total lung capacity due to underwater work performed with each start and turn (Cordain and Stager 1988). Whilst this restrictive breathing pattern suggests that oxygen consumption would be a limiting factor to performance, arterial blood samples taken during maximal swimming show similar values for oxygen saturation and oxygen pressure to that of maximal running with unrestricted breathing (Holmer *et al*. 1974). Swimmers consequently have been observed to have larger static lung volume compared to other athletes (Cordain *et al*. 1990); this may be the physiological adjustment needed in order to overcome the restrictive breathing patterns and aid the oxygen transport process needed for optimal performance.

2.6 Pacing strategies

Athletes and coaches are able to have a significant impact on a race performance by manipulating their pacing strategy. Foster et al (2004) define pacing strategies as the method of distributing workload and energy consumption throughout an exercise task in order to achieve the optimal overall performance. Strategies include: all-out (maximal effort throughout the event), positive split (decreasing speed throughout the event), negative split (increasing speed throughout the event), even split (maintaining speed throughout the event), and variable pace (fluctuations in exercise intensity or workload) (Abbiss and Laursen 2008). Whilst there are many different pacing strategies used, the main factors that influence pacing strategy selection are the athlete's anaerobic capacity and $\dot{V}O_{2max}$, event set-up along with the duration of the event.

Foster et al (1993) suggests there are two set-ups for racing events; 'head-to-head' or 'time trial'. During a 'head-to-head' event, athletes race against each other directly, thus allowing athletes to determine their pacing strategies based on their opponents. For athletes to be successful during this type of event, athletes only need to be marginally faster than their opponents and may often race slower than their best times. During a 'time trial' event, athletes race individual with the aim of posting the fastest time.

Short duration events, ≤ 30 s, benefit from an 'all-out' strategy where as longer events, > 120 s benefit from even pacing. Pacing strategies for these event durations appear to be universal across swimming, rowing, running and cycling. However, knowledge on optimal pacing for events lasting between 90 - 120 s is very limited. Abbiss and Laursen (2008) suggest that elite runners will often use a positive split pacing strategy in order to achieve best times. To the best of the researcher's knowledge, there have been no scientific investigations into pacing strategies used by 200 m swimmers.

2.7 Physiological Benefits of Warm Ups

Warm ups can enhance performance through their physiological effects on the body (Zochowski *et al*. 2007). Warm up protocols can be classified into two approaches; passive warm ups (raising core or muscular temperature by external means such as saunas or hot showers) and active warm ups (the use of exercise to raise temperature). Active warm ups appear to induce greater metabolic and cardiovascular changes than passive warm ups (Bishop 2003). Neiva *et al*.'s (2013) study supports this suggestion and observed a lower lactic acid accumulation during 30 s sprint intervals after an active warm up, compared to a passive warm up, even though the core and muscular temperature started at the same level. Chandler and Brown (2008) suggest that whilst there are a number of physiological effects associated with an active warm up, the most important are the elevation of core and muscular temperatures.

Warm ups are designed to prepare the body for the subsequent bout of exercise by increasing cardiovascular, muscular and metabolic function along with nerve conduction rate (McGowan *et al*. 2015, Zochowski *et al*. 2007). Studies have demonstrated performance improvements and a reduced risk of musculoskeletal injuries after completing a warm up. A temperature increase of 1ºC is enough to reduce the occurrence of injury on skeletal muscle due to a decreased muscle fibre stiffness and passive resistance in joints (Yaicharoen *et al*. 2012). This leads coaches and athletes to place great importance on their warm up procedures. However, the effects and ideal structure of the warm up is not well known (Neiva *et al*. 2011).

The muscle pH level and temperature will affect the muscles ability to generate force. Whilst acidosis or a reduction in the pH level in the muscle will cause fatigue and limit performance, mild lactic acidosis known as the Bohr Effect, can cause capillary vasodilatation and facilitate haemoglobin dissociation (Boning *et al*. 1991). Bangsbo *et al*. (1996) suggest that muscle pH should be 7.1 in order for optimal enzymatic reactions to occur and enhance the rate of metabolic reactions. Sargeant (1987) states that muscle warmed to 39.3ºC improves peak force and power output by 11% when compared to a resting body temperature of 36.6ºC. A higher temperature in active tissue assists the performance of work (Seto *et al*. 2005). An elevated temperature has also been associated with increasing the volume oxygen that is transported to the activated muscles due to increased vasodilation and blood flow along with an increase of oxygen release from both haemoglobin and myoglobin (Neiva *et al*. 2011). Haemoglobin is found in erythroctyes, or red blood cells, these carry the bulk of the oxygen in the blood whereas myoglobin carry the oxygen in the muscle tissue (Marieb 2002). Zochowski *et al*. (2007) state that haemoglobin detaches up to twice the amount of oxygen at 41ºC as opposed to 36ºC and that a similar effect is apparent with myoglobin. An increase in temperature can therefore reduce the oxygen deficit and elevate the volume of oxygen in the blood and muscles from its baseline (Ozyener *et al*. 2001). As a result, the aerobic metabolism rate of response is faster, allowing the initial work of the main activity or competitive performance to be complete with increased aerobic and decreased anaerobic contributions, thus sparing the anaerobic capacity for later in the task and subsequently reducing fatigue and increasing exercise tolerance (Neiva *et al*. 2011). This is providing the rest period between warm up and main activity is not long enough to allow the volume of oxygen to return to the baseline; Zochowski *et al*. (2007) suggest this could occur within roughly five minutes.

An elevation in temperature is expected to increase nerve conduction rate and speed of metabolic reactions, which is linked to improved speed and force of muscle contractions (Febbraio *et al*. 1996). These metabolic reactions include high energy phosphate degradation, glycolysis and glycogenolysis (Neiva *et al*. 2011). High energy phosphate degradation is the breakdown of the phosphate bonds in adenosine triphosphate which provide cells with energy. Glycolysis is the process that breaks down glucose molecule to form pyruvic acid and replenish two adenosine triphosphate molecules to create energy. Glycogenolysis is the process where glycogen is broken down into glucose in order to maintain blood glucose levels to provide fuel for the replenishment of more adenosine triphosphate (Marieb 2002). By increasing core and muscular temperature; these reactions occur at a faster rate, supplying the muscle with energy faster, thus enhancing the speed of the muscle contraction and the force generated.

A warm up can also have an effect on $\dot{V}O_2$ kinetics, known as priming (Ingham *et al*. 2013). Priming exercises performed at a high intensity can increase the amplitude of the primary component of $\dot{V}O_2$ kinetics, however moderate intensity exercise appears have limited effect (Burnley *et al*. 2000, Gerbino *et al*.. 1996). Burnley *et al*.'s (2001) study shows that prior heavy exercise increased the amplitude of the $\dot{V}O_2$ response, which remained elevated with the onset of a second high intensity exercise bout after a six minute recovery period;

meaning that during the second heavy exercise bout the absolute $\dot{V}O_2$ response was increased by ~160 ml min^{-1}. Priming exercises cause the primary component to predict a higher rate of work and increase the volume of oxygen uptake to match the prediction, subsequently reducing the slow component and associated decrease in muscle efficiency and increase in levels of fatigue and energy cost (Rossiter *et al*. 2002). This effect is known as speeding of $\dot{V}O_2$ kinetics and provides a greater supply of oxygen at the beginning of exercise; resulting in an enhanced tolerance to subsequent high intensity exercise and can increase time to exhaustion by 15% to 30% (Bailey *et al*. 2009). Whilst many studies support the inclusion of priming exercises (Bailey *et al*. 2009, Bailey *et al*. 2016, Burnley *et al*. 2000, Ingham *et al*. 2013, Jones *et al*. 2003), they could cause fatigue and impair performance. Athletes should allow a recovery period in between the priming exercises and the beginning of their competitive performance. Ingham *et al*. (2013) suggest that five to nine minutes of passive recovery will allow the body to recover from fatigue whilst maintaining the effects of speeding up of $\dot{V}O_2$ kinetics.

Neiva *et al*.'s (2011) study states that performing a warm up will improve the maximum and mean propelling force in a front crawl competitive performance, without causing any significant difference in lactate accumulation or rate of perceived exertion, when compared to racing without a prior warm up. However Neiva *et al*. (2011) do not provide any information on the structure or composition of the warm up. In order for athletes to benefit from the effects of increased temperature and a speeding of $\dot{V}O_2$ kinetics, a warm up should be constructed to include activities that manipulate the intensity, duration and recovery time to elicit these effects (Neiva *et al*. 2013). There are many conflicting opinions with regard to warm up intensity in Senior athletes and adult participants. Chmura (2000) states it should be below 50% of $\dot{V}O_{2max}$ whereas Stewart and Sleivert (1998) suggest it should be 50-70% of $\dot{V}O_{2max}$ and Yaicharoen *et al*. (2012) state it should be 70-80% $\dot{V}O_{2max}$. However these authors do agree the higher the warm up intensity that is employed, the shorter the duration that is recommended. Tyka (1995) reported improved performance in the Wingate test with warm up below 50% of $\dot{V}O_{2max}$ when compared to 70% of $\dot{V}O_{2max}$. However Bishop *et al*.'s (2002) study (participants aged 22 ± 4 years), and Burnley *et al*.'s (2001) study (participants aged 27 ± 4 years) suggest that a low intensity warm up could be insufficient to activate the physiological and metabolic processes needed to enhance energy production, e.g. glycolysis and $\dot{V}O_2$ kinetics. Makaruk *et al*. (2008) suggest that a 10 min, high intensity warm up improves performance in younger athletes (age 15.7 ± 0.5 years) during sprints compared to a 20 min, moderate intensity warm up. Yaicharoen *et al*.'s (2012) study (participants aged 24.5 ± 6.7 years) supports this and suggests that performing a 10 min warm up at an intensity between 70-80% of an athlete's $\dot{V}O_{2max}$ results in an increase in core and muscular temperature and does not deplete phosphocreatine stores needed for sprint performance. There are many conflicting opinions on the effect of intensity in Youth and Senior athletes in dry land modes of exercise however the present author is aware of only three studies that have focused on the effect of warm up intensity on swimming performance (Balilionis *et al*. 2012, Houmard *et al*. 1991, Neiva *et al*. 2016). Balilionis *et al*.'s (2012) study (participants aged 19.8 ± 0.7 years) compared no warm up, short warm up (50 yards at 40% of swimmers' maximal effort and 50 yards at 90%) and swimmers' usual pre-competition warm up (warm up distance 1314 ± 109 m). No intensities were detailed other than heart rate before the performance test. The usual pre-competition warm up heart rate was significantly higher than the short warm up heart rate; 100 ± 13 $b.min^{-1}$ and 92 ± 19 $b.min^{-1}$ respectively). These results state that the swimmers usual pre-competition warm up was most effective; perhaps suggesting a more intense warm up would enhance swimming performance. It is difficult to distinguish whether these improved results in the usual pre-competition are due to the increased intensity or that the duration and distance of the warm up was greater. Houmard *et al*.'s (1991) and Neiva *et al*.'s (2016) studies (participants aged 20.8 ± 0.6 years and 17.15 ± 1.52 years, respectively) compared high and low intensity warm ups consisting of the same distance. These authors reported no statistically significant difference in the performance results and propose there is no benefit to designing high intensity warm up programmes. To the best of the present author's knowledge the effect of intensity has not been studied in Age Group swimmers.

Whilst Neiva *et al*.'s (2016) study did not show a statistically significant difference 100 m freestyle performance, they report the different warm up protocols induced differing physiological effects. The low intensity warm up included a short race pace set, usual to most pre-competition warm up routines (4 x [25 m race pace + 25 m easy]), whereas the high intensity warm up included a short set designed to stimulate aerobic metabolism and potentially cause a speeding of $\dot{V}O_2$ kinetics. The high intensity warm up induced higher oxygen uptake, heart rate and core temperature with a lower blood lactate concentration compared to the low intensity warm up. However these differences abated during the 10 min passive recovery period. Despite similar performance outcomes, biomechanical and physiological responses differed between performances. The high intensity warm up produced a lower blood lactate concentration and a higher core temperature immediately after the performance compared the low intensity warm up. Also the high intensity warm up triggered a higher stroke length value as well as a higher stroke efficiency value during the first 50 m lap, whereas in the low intensity warm up swimmers achieved a higher stroke frequency. Whilst this resulted in similar performance over 100 m freestyle, a higher intensity warm up that lowers blood lactate concentration and increases stroke length and stroke efficiency could result in enhanced performance over a longer distance swim.

Although effective warm up strategies are determined by the intensity and duration of the warm up, the transition between the end of the warm up and commencing the competitive event can have a significant influence on the physiological preparedness of the athlete (McGowan *et al*. 2015). Many studies have demonstrated the effects of $\dot{V}O_2$ kinetics can be maintained after a five to nine min recovery period (Burnley *et al*. 2000, Ingham *et al*. 2013) and significant improvements in 200 m freestyle performance have been shown by reducing the transition time from 45 min to 10 min (West *et al*. 2013, Zochowski *et al*. 2007). The recovery period should be long enough to allow the re-synthesis of phosphocreatine stores but short enough so that the core and muscular temperature and volume of oxygen remain elevated. 95% of phosphocreatine can be re-synthesised within four min (Volek 2001). Peak power has been reported to improve following a six min recovery period after a high intensity warm up (Sargeant and Dolan 1987). Volume of oxygen can return to the baseline within five min. Core and muscular temperature is significantly reduced following 15 to 20 min of passive recovery therefore a recovery period of at least five min but less than 15 min will provide the optimum effects of the warm up. In order to correctly observe the magnitude of the effects of different warm up intensities, the performance tests need to be carried out as close to the end of the warm up as possible once the participant's heart rate has significantly decreased to ensure they have recovered from the warm up exercise

(Zochowski *et al*. 2007). Participants in this study were only given a five min transitional period. During the transitional phase, the participants were instructed to dry off, remain seated and to stay hydrated.

2.8 Current Swimming Warm Ups at Competition

At the ASA South West Regional Championships, swimmers are given 30 min in the pool to complete their warm up. Due to the large number of swimmers competing, the warm ups are split by gender (see appendix B); meaning that the first event of the session can be up to an hour after the start of the first warm up period. Swimmers can wait up to two hours between their warm up and their first race. Before entering the water, swimmers tend to complete a basic range of flexibility exercises focusing on increasing the range of movement in the shoulder and hip joints and lower back. Usually swimmers then complete 400-600 m of low intensity swimming, including some drill and stroke practices, followed by some practice starts with 15 m sprints. Swimmers leave the pool, change into their racing costume and wait to be called by the coach to get ready for their race. They will go through their race plan with their coach and report to marshalling 15 to 20 min prior to their race. At Age Group competitions transitional phases of 30 to 45 min are very common. Swim coaches are offered conflicting opinions by coaching manuals with some suggesting brief, low intensity warm ups (Colwin 2002, Wright and Copland 2004) and others suggesting longer, higher intensity warm ups (Brooks 2011, Salo and Riewald 2008) leading coaches to make their own warm up protocols based on trial and error rather than scientific research. Swim coaches commonly apply a low intensity warm up as it is traditionally thought that this would save energy for the race by maintaining the glycogen stores and limit the risk of fatigue through the build-up of lactic acid associated with a higher intensity warm up. This is supported by Gossen and Sale’s (2000) study that reported a fatiguing effect after a high intensity warm up involving isometric knee extension. These warm ups seem to be based completely on mobilization of joints and performing skills with best technique, without consideration for the physiological responses needed to enhance performance.

Core and muscular temperature rise more slowly in an aquatic environment because the water temperature in a swimming pool (between 27°C and 29°C) is below skin temperature. Due to the lower temperature, Zochowski *et al*. (2007) suggest that swimmers will need to perform a longer and more intense warm up in order to increase core and muscular temperature to the level related to performance improvements. A high intensity warm up will produce elevated core and muscular temperature which theoretically would result in a better performance. A low intensity warm up will elevate the temperature to a lesser extent therefore, in principle, it would not prepare the body as successfully for a race. However, to date there has been no systematic investigation of the effects of warm up intensity on swimming performance.

Whilst coaching manuals state that warm ups should focus on performing skills with best technique, most swimmers performing low intensity aerobic swimming tend to drop their kick pattern to a two or four beat kick rather than maintain the optimal six beat kick which has been shown to enhance distance per stroke, increase rotation and improve stabilisation of the trunk assisting in streamlining (Sortwell 2011). A low intensity swim using a two or four beat kick pattern would not be considered by many coaches as best technique. During the race a strong six beat kick will be required for optimal performance (Gatta *et al*. 2012), therefore ensuring an elevated muscular temperature in the legs is a key priority for the warm up. It is not conventional for swim coaches to include isolated kick practices (without the use of arms) during the warm up (Brooks 2011, Colwin 2002, Wright and Copland 2004, Salo and Riewald 2008). Whilst the kick pattern during the race will have very limited direct propulsion, it indirectly has a significant impact on maximal swimming speed. Coaches are aware of the important role kick plays in a race which often leads to a fear that warm ups which include isolated kick exercises will result in lactic acid accumulation and fatigue the legs rather than ensure that they are sufficiently primed and ready to work at maximum intensity. Dropping to a two or four beat kick pattern during an aerobic swim may be insufficient to raise the muscle temperature. Comparatively, integrating an isolated kick exercise into the warm up will encourage a greater amount of blood flow to the large muscle groups that perform the kick action and thus potentially preparing them better for the subsequent performance. However, to date there has been no systematic investigation of the effects of isolated kick practices on swimming performance.

2.9 Summary of Literature Review

In summary, swimming is an early specialisation sport demonstrated by Youth swimmers competing at the highest level. England Talent Programmes focus on current results of Age Group swimmers rather than identifying future potential. In order to be selected for the first phases of England Talent Programmes training camps, Age Group swimmers require successful competitive performance; lending the primary focus to competition which is contrary to academic research which suggests Age Group training should be focused on aerobic development.

Studies have shown that children develop through maturation at differing rates; therefore children of the same chronological age have differing physical characteristics such as height, weight and somatotype (Iuliano-Burns *et al*. 2001, Malina *et al*. 2006, Malina and Geithner 2011). Tests have shown maturity-related difference in speed, strength and stamina (Katzmarzyka *et al*. 1997), and physical stature has been shown to influence swimming performance (Grimston and Hay 1986). Training for Age Group athletes can be a significant contributor to $\dot{V}O_{2max}$, whereas sexual and skeletal maturities are significant contributors to speed and muscular strength and power. Early maturing athletes have a distinct advantage in Age Group competition and therefore more chance of being selected for British Swimming Talent Programmes. Coaches try to produce a training programme which follow the LTAD framework but also must create strategies to maximise performance of both early and late maturing athletes; of which warm ups should be considered.

200 m front crawl performance is a one-off maximal effort swim at an intensity close to or at an athlete's $\dot{V}O_{2max}$, lasting slightly over two min. Long efficient arm strokes performed with a high stroke frequency and a continuous kick are needed for optimal swimming performance (Sortwell 2011). Efficient and effective stroke mechanics rely heavily on the strength of the legs to produce a consistent kick pattern (Gatta *et al*. 2012) and starts, turns and transitions rely on leg power (Breed and Young 2002) therefore it may be necessary to include activities in the warm up that target the leg muscle groups. Many studies have demonstrated that $\dot{V}O_{2max}$ and the amplitude of the primary component of $\dot{V}O_2$ kinetics are directly correlated to average speed (Sousa *et al*. 2011, Figueiredo *et al*. 2011, Figueiredo *et al*. 2013, Strzala *et al*. 2015, Lätt *et al*. 2010). Increasing the amplitude of the primary

component of $\dot{V}O_2$ kinetics will reduce the contribution of the anaerobic metabolism during the first 50 m lap and subsequently reduce fatigue and increase exercise tolerance. Enhancing the amplitude of the primary component of $\dot{V}O_2$ kinetics should be of consideration for the warm up.

The effects and ideal structure of the warm up is not well known (Neiva *et al*. 2011). Whilst swim coaches place great importance on their warm up procedures, they are offered conflicting opinions by coaching manuals on the duration and intensity, leading coaches to make their own warm up protocols based on trial and error rather than scientific research. Warm ups can enhance performance through their physiological effects on the body (Zochowski *et al*. 2007); the most important effects are suggested to be the elevation of core and muscular temperatures. A temperature increase of 1ºC is enough to reduce the occurrence of injury. Sargeant (1987) states that muscle warmed to 39.3ºC improves peak force and power output by 11% when compared to a resting body temperature of 36.6ºC and Zochowski *et al*. (2007) state that haemoglobin detaches up to twice the amount of oxygen at 41ºC as opposed to 36ºC and that a similar effect is apparent with myoglobin. Cardiovascular, muscular and metabolic function along with nerve conduction rate can all be increased by completing a warm up (Zochowski *et al*. 2007). Bangsbo *et al*. (1996) suggest that muscle pH should be 7.1 in order for optimal enzymatic reactions to occur and enhance the rate of metabolic reactions. Priming exercises can increase the amplitude of the primary component of $\dot{V}O_2$ kinetics through an effect known as a speeding of $\dot{V}O_2$ kinetics. This means the primary component will predict a higher rate of work and increase the volume of oxygen uptake to match the prediction, subsequently reducing the slow component and associated decrease in muscle efficiency and increase in levels of fatigue and energy cost (Rossiter *et al*. 2002). Whilst many studies support the inclusion of priming exercises (Bailey *et al*. 2009, Bailey *et al*. 2016, Ingham *et al*. 2013, Jones *et al*. 2003), they can cause fatigue and impair performance. Therefore athletes should allow a recovery period in between the priming exercises and the beginning of their competitive performance. This study will compare the results of a 200 m freestyle performance using different warm up protocols that manipulate intensity and include or exclude isolated kick practise.

In order to approach this question scientifically, intensity will be quantified using an objective measure and prescribed as an internal and external workload. A pilot study was conducted to ascertain if blood lactate testing would be an appropriate method to quantify internal workload. The external workload was prescribed as a percentage of MAS.

Chapter 3

Methods

3.1 Pilot Study

3.1.1 Aims and Participants

A pilot study was conducted using seven males and two females (age 12 ± 1.73yrs). The aim of the pilot study was to ascertain if blood lactate testing should be used to quantify exercise intensity. All participants provided written informed consent to participate in this study. Written informed consent was also provided by the participant’s parent or guardian. This study was approved by the University of Gloucestershire’s Research Ethics Committee (see appendix K).

3.1.2 Method

The method follows that set out by Maglischo (2003) using an incremental 5 x 300 m incremental swim test. Participants arrived on poolside 5 min before the start of the session where they were instructed to sit down in order to take a resting blood lactate sample. Participants then completed five 300 m swims with a one min rest period after each swim trying to swim faster than the previous 300 m swim repeat. All swims were started in the water with a push and swimmers were instructed to swim at an even pace throughout. Blood samples were taken after each of the 300 m swim repeats. Heart rate and rate of perceived exertion were also recorded after each 300 m swim repeat. Fingertip capillary blood samples were drawn and assayed for blood lactate concentration using a Lactate Pro Blood Lactate Test Meter. A risk assessment on blood sampling was completed (see appendix L).

3.1.3 Results

Table 3.1 shows the Mean ± SD blood lactate concentrations and time of the 300 m incremental swim test. For complete result please see appendix C. All participants increased their speed significantly across each 300 m swim repeat, and therefore the external workload has incrementally increased throughout the test. Participants displayed significant variations in resting blood lactate concentrations with many showing elevated concentrations before commencing exercise. Many participants' concentrations showed their lowest value on the second and third swim repeats, suggesting that the internal workloads are at their lowest. Participants M4 and F1 showed a lower blood lactate values on their highest external workload than the previous lower external workload. The internal and external workloads did not match up during the study.

Table 3.1 Mean ± SD blood lactate measure (mM) and time (s) of 300 m incremental swim test.

	Time (s)	Blood Lactate (mM)
Resting		1.1 ± 0.7
Step 1	310 ± 20	1.5 ± 0.5
Step 2	289 ± 17	1.0 ± 0.6
Step 3	270 ± 9	1.8 ± 1.2
Step 4	258 ± 11	2.7 ± 1.3
Step 5	245 ± 11	4.3 ± 2.0

3.1.4 Conclusion

The majority of the participants did not reach the required blood lactate reference point of 4 mM in order to set the high intensity swimming speed for the warm up protocols (see appendix C). The results of this pilot study are in line with other literature on blood lactate responses in children at or close to $\dot{V}O_{2max}$ (Tolfrey and Armstrong 1995). As blood lactate may under predict intensity; this method was disregarded and the performance measure of MAS was the sole method used for quantifying exercise intensity.

3.2 Participants and Recruitment

This study was approved by the University of Gloucestershire's Research Ethics Committee (see appendix K). The researcher holds an Enhanced DBS Certificate in order to work with children (see appendix D). Swimmers were eligible for the study if they had competed at the 2015 ASA South West Regional Championships. Seventeen competitive Age Group swimmers (n = 9 males, age 12 ± 1.22yrs, stature 1.58 ± 0.10m, mass 49.3 ± 9.75kg; n = 8 females, age 12 ± 0.99yrs, stature 1.58 ± 0.09m, mass 48.6 ± 7.79kg) were recruited and provided written informed consent to participate in this study (see appendix E). The consent form explains the participants' right to anonymity and confidentially along with their right to withdraw from the study. Informed consent was also provided by the participant's parent or guardian (see appendix F) and they completed a health questionnaire (see appendix G/H) to ensure they were fit and healthy to participate in the study. Throughout the testing procedures participants were asked to follow their normal training routine. They were asked to attend each testing session well hydrated, having avoided caffeine for three hours prior to testing, suspended their normal training 12 hours prior to testing, and to have followed their usual competition preparation strategy. All tests were separated by at least 24 hours.

3.3 Study Design

This study used a repeat measures design. Participants were tested on five occasions over a two week period at the end of the competition phase of training. The first session was utilised to determine the intensity of swimming efforts. The remaining four sessions tested different warm up protocol designs. All pool based experiments were complete in a 25 m indoor swimming pool. Water and air temperature was measured at the start of each session by the Leisure Centre's Duty Manager using a hand held pool thermometer (AQUATEMP waterproof thermometer manufactured by E.T.I. Ltd), and a wall mounted thermometer (Defiance Max / Min push button thermometer), temperature readings fell within 28°C - 29°C and 29°C - 30°C respectively. Humidity was also recorded using an air duct senor (Trend Duct Humidity & Temperature Sensor HT/D/2%) and measured ~55%. Participants were tested in morning (starting at 8.00am) as per their normal competition routine. All testing protocols follow similar patterns to their own training and competition sessions and therefore the researcher decided that the participants did not require a familiarisation session. The determination of the order of the warm up test was counterbalanced. Assessments were conducted in the mornings so that the researcher could adhere to following pre testing procedures (1) refrain from consuming food for at least two hours before assessment (2) refrain from exercising for a twelve hour period before assessment (3) to empty their bowel and bladder before assessment (4) to wear swimming costume/shorts (where appropriate) and (5) to remove all jewellery. For logistical reasons, all participants followed the same testing procedures. Participants were asked to wear the same swimming costume, hat and goggles for every swimming testing session. With the cooperation of the regular coaches, training volume and intensity were kept as consistent as possible throughout the duration of the study.

3.4 Test Protocols

3.4.1 Determination of exercise intensity test

To evaluate maximal aerobic speed, the participants completed a five min maximum effort swim time trial test (Barker 2011). The aim was to cover the maximum distance possible in five min. The distance covered measured to the nearest metre and using *Eq1* 100% of maximal aerobic speed (MAS) was calculated. Participants were set individual external workloads using *Eq2* and *Eq3* of low intensity (LI = 70% of MAS) and high intensity (HI = 90% of MAS). These percentages for maximal aerobic speed were calculated into 50 m split times so that the participants can swim at the required workload.

Participants were given a 20 min warm up phase to complete their own warm up and a five min transitional phase of passive recovery before conducting the five min time trial. During the transitional phase the participants were instructed to dry off, remain seated and to stay hydrated.

3.4.2 Warm up test

Four different warm up protocols were designed to manipulate the two variables; kick and intensity as low intensity without kick (control group as this is similar to the participants' standard warm up protocols), low intensity with kick, high intensity without kick and high intensity with kick. To ensure the reliability and validity of the testing, each exercise bout during the warm up was set for a time rather than distance, i.e. low intensity freestyle swim for six min as opposed to low intensity freestyle swim for 400 m. This aims to reduce the impact of stroke technique affecting the desired physiological response because a more efficient and effective technique will complete a set distance in a short time frame and may not produce the desired physiological response (Barbosa *et al*. 2008). In order to isolate these physiological factors, many parts of a standard competition warm up had been removed as they may impact the results. These warm up protocols have not included any skill, psychological or tactical preparation. The tests were completed in a counterbalanced order using a Latin square design. Table 2 shows the warm up procedures that were tested.

Table 3.2 Warm up protocols

Warm up protocols				
1.	5 min pre-pool programme			
2.	2 min easy front crawl swim			
3.	**LW:** 6 min front crawl swim @ 70%MAS	**LK:** 6 min front crawl swim @ 70%MAS 2 min front crawl kick holding kick board	**HW:** 6 min front crawl swim @ 90%MAS	**HK:** 6 min front crawl swim @ 90%MAS 2 min front crawl kick holding kick board
4.	2 min easy front crawl swim			
5.	5 min passive recovery period			

Condition: LW = low intensity without kick, LK = low intensity with kick, HW = high intensity without kick, HK = high intensity with kick

All warm up protocols started with a pre-pool programme (a routine of land based exercises (see Appendix K) designed to mobilise joints and activate key muscle groups). The participants were given five min to work through as much of the programme as possible. The participants then entered the water and swam front crawl at a low and comfortable intensity. During the warm up protocols the researcher used a whistle to signal the end of each section. Upon hearing the whistle, participants returned to the end wall before starting the next section. Participants then swam at set target intensity for six min. This target intensity swimming pace was set based on their maximal aerobic speed. The researcher explained to the participant what their target 50 m split time should be for the intensity swim. A card was shown to the participant as they exited each 50 m tumble turn in order to allow the participant to understand the pace they are swimming and encourage them towards the prescribed pace. If the participant was required to increase their swimming pace the card they were shown stated 'FASTER'. If the participant needed to reduce their speed to meet the desired pace the card stated 'SLOWER'. If the participant was swimming at the correct pace the card stated 'GOOD PACE'. These cards were also colour coded for the ease of understanding by the participants. At the end of the six minutes the whistle was blown and the participants returned to the end wall. If the warm up protocol prescribed kick, the participants then completed two min of steady front crawl kick using a float or kick board, then finally the participants were given one min of low comfortable intensity front crawl swimming before exiting the pool.

Following the warm up protocols, the participants had five min passive recovery where they were instructed to get dry, sit down and stay hydrated before they swam a 200 m freestyle time trial at maximum effort. The time trial was timed manually on a stopwatch and recorded to 0.01 s. 50 m split times were also recorded in order to identify and understand variances in performance. The participants were allowed to complete a swim down of their choice before exiting the pool.

3.5 Data Analysis

All data was checked for normality using the Shapiro-Wilk test. Data was found to be acceptably normal, and analyzed using two-way repeat measures ANOVA. For total 200 m time a two-way ANOVA intensity by kick was performed. Fifty metre split times were investigated using a two-way condition by distance ANOVA, this was preferred to a three-way analysis which would be difficult to interpret. For all statistics, the significance level was set at $P < .05$ and the magnitude of the effect was measured by ETA^2. Data are presented as mean and SD unless otherwise stated.

Chapter 4

Results

4.1 MAS test

The MAS test results show a mean speed of 1.16 $m.s^{-1}$ ± 0.11 $m.s^{-1}$, 70% of MAS a mean of 0.81 $m.s^{-1}$ ± 0.08 $m.s^{-1}$ and 90% of MAS a mean of 1.04 $m.s^{-1}$ ± 0.10 $m.s^{-1}$.

4.2 200 m Time trial

Table 4.1 shows the mean ± SD of total times for each warm up protocol and Figure 4.1 shows the differences in total time. The two-way ANOVA test showed that there was no significant interaction effect between Intensity*Kick (P=0.171 - ETA^2 0.114), or main effect for Intensity (P=0.131 - ETA^2 0.137) and main effect for Kick (P value 0.692 - ETA^2 0.010).

Table 4.1 Mean ± SD values of lap times for each warm up protocols

Total Times	**50 m**	**100 m**	**150 m**	**200 m**
Condition				
LW (s)	36.81 ± 3.34	79.02 ± 7.61	122.95 ± 12.24	164.98 ± 16.23
LK (s)	37.00 ± 3.66	79.63 ± 8.48	123.48 ± 12.52	165.78 ± 16.57
HW (s)	36.80 ± 3.30	78.30 ± 7.37	122.64 ± 11.34	164.92 ± 14.74
HK (s)	36.89 ± 3.23	78.91 ± 7.42	122.76 ± 11.10	164.39 ± 16.39

Condition: LW = low intensity without kick, LK = low intensity with kick, HW = high intensity without kick, HK = high intensity with kick

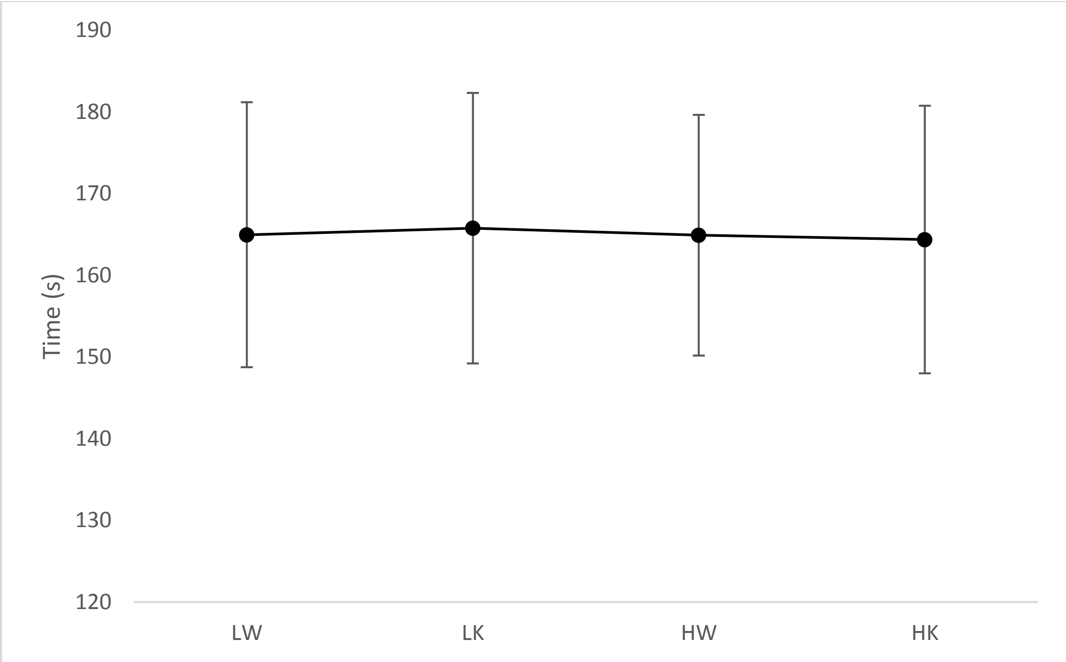

Figure 4.1 Mean ± SD values of total time for each warm up protocols. Condition: LW = low intensity without kick, LK = low intensity with kick, HW = high intensity without kick, HK = high intensity with kick

Table 4.2 shows the mean ± SD of split times. The two-way ANOVA test showed that there was no significant interaction effect between Condition*Distance (P=0.796- ETA2 0.029 – small effect size) or main effect for Condition (P=0.701 - ETA2 0.029 – small effect size). Main effect for Distance was statistically significant (P=<0.001 - ETA2 0.905 – large effect size). Main effect on Distance has been represented graphically in Figure 4.2 and has reported that there is a difference on split times as the participants are progressing through each split. This difference is account from by the pacing strategy used by the swimmers.

Table 4.2 Mean ± SD values of split times for each warm up protocols

Split Times	**50 m**	**100 m**	**150 m**	**200 m**
Condition				
LW (s)	36.81 ± 3.34	42.21 ± 4.36	43.93 ± 4.77	42.03 ± 4.21
LK (s)	37.00 ± 3.66	42.62 ± 4.92	43.85 ± 4.17	42.12 ± 4.25
HW (s)	36.80 ± 3.30	42.11 ± 4.32	43.74 ± 3.89	42.11 ± 3.40
HK (s)	36.89 ± 3.23	42.21 ± 4.28	43.67 ± 3.88	41.75 ± 3.78

Condition: LW = low intensity without kick, LK = low intensity with kick, HW = high intensity without kick, HK = high intensity with kick

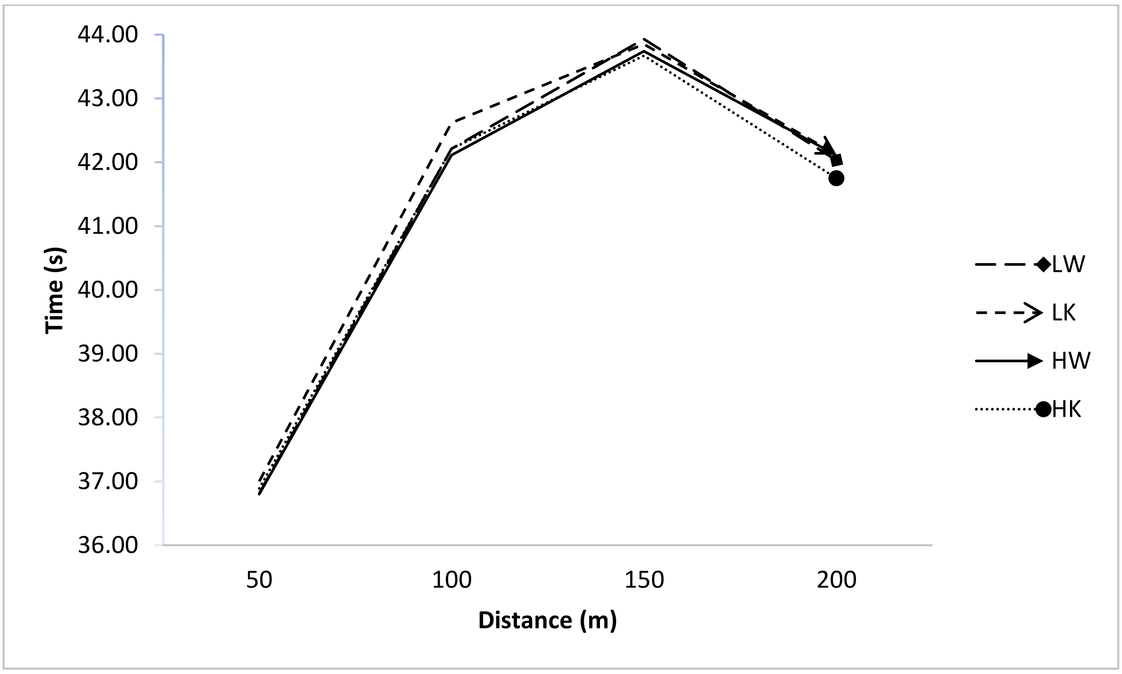

Figure 4.2 Mean values of split times across each warm up protocols. SD error bars are omitted for clarity of trend across four different warm up protocols. SD can be seen in table 4.3.

Chapter 5

Discussion

5.1 Key Findings

The aims of the present study were (1) to compare the effect of high and low intensity warm ups on 200 m freestyle time trial results of Age Group swimmers; and (2) to compare the effects of warm ups that include and exclude an isolated kick practice on 200 m freestyle time trial results of Age Group swimmers. The key findings of this study is that there was no statistically significant change in 200 m freestyle time trial results of Age Group swimmers in respect of total time or split times when manipulating intensity and kick variables during the warm up. The results of the present study support the findings of Neiva *et al*.'s (2016) and Houmard *et al*.'s (1991) studies who both found no statistical significant differences to performance after high and low intensity warm ups. Neiva et al.'s (2016) study showed that there was a difference in stroke frequency and stroke efficiency during their 100 m freestyle performance tests. The high intensity warm up produced a more efficient stroke with a lower stroke rate; this would be the desired stroke mechanics for 200 m freestyle swimming. Combined with their physiological differences after the performance tests, the high intensity warm up displaying higher core temperature and lower blood lactate values would suggest an enhanced exercise tolerance and improved time to exhaustion. These physiological differences would be the desired response during a 200 m freestyle swim. However the pacing of the 200 m freestyle performance tests remained the same for all warm up protocols which could suggest that the warm up protocols did not stimulate any physiological and mechanical differences or that they have had no effect on the overall performance. This study is unable to state for certain that there was any physiological or mechanical differences due to warm up protocols as these measures were not taken. The results highlighted a common pacing strategy used by all participants. It may be difficult to fully understand to the requirements of the warm up to produce a state of physiological preparedness without further research into why this particular pacing strategy is employed in 200 m swimming.

Whilst kick has limited direct propulsion, in stabilising the trunk it improves body position and reduces the amount of resistance incurred by the athlete (Gatta *et al*. 2012). Overall stroke efficiency and maximal swimming speed are affected by the kick pattern. The results of this study suggest that including two min of isolated kick practise in the warm up does not appear to enhance performance by encouraging blood flood to the larger muscles groups and increasing muscular temperature. Also kick does not appear to produce a fatiguing effect through a build up of lactic acid that many coaches suspect. The results of this study suggest that excluding isolated kick from the warm up, again, appears to have very little bearing on performance. These results may suggest that low intensity aerobic swimming where athletes adopt a two or four beat kick pattern may be sufficient to raise the muscle temperature in the legs. Therefore it may not be necessary to include kick in a warm up to achieve optimal performance but similarly including two minutes of kick appears not to impair performance. To the best of the researcher's knowledge, there is currently no other research investigating the effects of kick during a warm up on performance in swimming to compare with the results of this study.

Whilst the normal temperature of water in a swimming pool (between 27ºC and 29ºC) causes core and muscular temperature to rise at a reduced rate to equivalent dry land activities, contrary to the suggestions made by *Zochowski et al.'s* (2007) study, the results of this study suggest that swimming at 70% of MAS for six min appears to be sufficient to raise temperature for optimal performance. These results suggest that swimming at 90% of MAS for six min does not appear to enhance performance by having a priming effect unlike observations in running studies (Bailey *et al*. 2009, Bailey *et al*. 2016, Ingham *et al*. 2013, Jones *et al*. 2003) nor does it appear to fatigue the swimmer or have a detrimental effect on performance. Swimming at 70% or 90% of MAS for six min appears to have limited effect on performance therefore it is unnecessary for athletes to warm up at this higher intensity but similarly will not impair performance if athletes do warm up that a higher intensity and is supported by the results of Neiva *et al*.'s (2016) and Houmard *et al*.'s (1991) studies.

The results of this study suggest there is not a coupling effect with the kick x intensity variables either; there was no statistical significant difference when utilising both variables compared to forgoing both variables. Many studies state that a warm up will improve the maximum and mean propelling force in front crawl (Neiva *et al*.'s 2011, Neiva *et al*. 2013, Zochowski *et al*. 2007), however these studies do not elaborate on structure or content of the warm up. The present study's results appear to show that completing a 14 to 16 min warm up is sufficient to achieve an optimal performance, however, the content focused on physiological responses of the warm up seems to have little influence on the overall outcome of the performance. Coaches might be correct in focusing their warm up protocols on performing skills with best technique rather than physiological preparedness; this supports the findings of Ajemian *et al*.'s (2010) study in reference to the relevance of motor learning during the warm up. The authors suggest that the warm up is necessary to restore an athlete's skills to a fine tuned state. Neiva *et al*.'s (2014) study concluded that warming up led to significant improvements in the stroke mechanics, yet the assessed physiological and psychophysiological variables did not seem to be influenced. These findings evidence the positive influence that usual warm up have on swimming performance, which appears to be mostly related to the swimmers' technical pattern. It is worth noting that many Age Group swimmers would compete in multiple events during the same session with only one warm up and many have up to one hour transition period. Given that there was no significant performance improvement across the warm up protocol, even with a short transitional period and only one focused time trial; the practical application of these findings suggests that Age Group swimmers should warm up at a low intensity without isolated kick practice as it is no proven performance benefit in doing anything more.

5.2 Pacing Strategy

The energy cost of 200 m freestyle swimming is comparable to that of 800 m running, but significant differences across the two sports in their approaches to racing may account for why priming activities appear to be successful in running but not in swimming. Pacing strategies in running focus on a positive split whereby the first half of the race is faster than the second (Foster *et al*. 1994, Tucker *et al*. 2006). World recorder holder David Rudisha (48.9 s, 52.1 s), and other world class runners Wilson Kipketer (49.3 s, 51.8 s), Joaquim Cruz (49.7 s, 52.0 s) and Sebastian Coe (49.7 s, 52.0 s) all employ this race profile (Speed Endurance 2016). It is therefore understandable that 800 m runners are reaching the severe intensity, close to $\dot{V}O_{2max}$, quickly in the race. As demonstrated in a number of studies (Bailey *et al*. 2009, Bailey *et al*. 2016, Ingham *et al*. 2013, Jones *et al*. 2003), 800 m runners who complete a warm up that includes high intensity priming activities that speed $\dot{V}O_2$ kinetics and provide a greater amount of oxygen at the beginning of the race, spare the anaerobic metabolism for later in the race meaning that they are able to significantly improve their exercise tolerance and performance.

In swimming, pacing strategies are focused on negative splitting, where the athletes aim to conserve energy during the first half in order to swim at maximum effort in the second. The race profile observed in this study (see fig 4.3) is a very common strategy used by elite Age Group, Youth and Senior swimmers. Table 5.1 shows the race profile and pacing strategy for men's and women's 200 m freestyle world records (Swimming World 2016) and the 2016 British Summer National Championships medallist for boys and girls aged 13/14, 15, 16 years (British Swimming 2016). The mean ± SD of the elite race profile for each 50 m split (s) is 27.94 ± 1.34, 30.22 ± 1.64, 30.58 ± 1.63 and 29.94 ± 1.74 respectively.

Table 5.1 200 m Freestyle race profiles

	50 m	100 m	150 m	200 m	Total time
Mens L/C world Record	24.23	25.89	26.18	25.70	102.00
Womens L/C world Record	27.34	28.26	28.78	28.60	112.98
Girls 13/14 years 1st	29.78	32.34	32.05	30.95	125.12
Girls 13/14 years 2nd	29.54	32.13	31.43	32.00	125.15
Girls 13/14 years 3rd	29.32	32.61	32.63	31.78	126.43
Boys 13/14 years 1st	27.80	29.61	29.89	29.73	117.03
Boys 13/14 years 2nd	28.15	29.89	31.08	29.85	118.97
Boys 13/14 years 3rd	28.23	30.65	31.80	29.36	120.04
Girls 15 years 1st	28.33	31.16	31.01	30.04	120.54
Girls 15 years 2nd	29.09	31.47	31.35	31.23	123.14
Girls 15 years 3rd	29.26	31.16	31.52	31.28	123.22
Boys 15 years 1st	26.49	29.39	29.94	29.37	115.19
Boys 15 years 2nd	27.26	29.22	29.56	29.29	115.33
Boys 15 years 3rd	27.00	29.68	30.02	29.33	116.03
Girls 16 years 1st	28.49	31.11	32.19	32.29	124.08
Girls 16 years 2nd	28.68	31.34	32.39	31.68	124.09
Girls 16 years 3rd	29.02	31.66	32.40	32.09	125.17
Boys 16 years 1st	26.74	29.03	28.98	27.34	112.09
Boys 16 years 2nd	27.14	28.94	29.23	28.20	113.51
Boys 16 years 3rd	26.83	28.94	29.25	28.72	113.74
Mean	27.94	30.22	30.58	29.94	
SD	±1.34	±1.64	±1.63	±1.74	

This pacing strategy mirrors a 'head-to-head' design, where athletes do what is necessary to win rather than achieve a best time. During a 'head-to-head', the actions of the opponents will influence the race dynamics and strategies employed. Most athletes will aim to do just enough during the beginning and middle sections of the race, conserving as much energy as possible for the sprint finish in order to win. During a 'head-to-head', often it is the athlete who is most efficient during the beginning and middle sections that win as they have much more to give during the sprint finish. In comparison, 'time trial' pacing strategies are aimed at achieving best times and, notably world record times, use either positive or even splitting across the beginning, middle and finishing sections of the race. However, the 200 m freestyle world record split times follow a 'head-to-head' strategy rather than a 'time trial' strategy which would suggest that there are other factors influencing the pacing strategy employed by elite swimmers.

The starting dive and subsequent transitional underwater phase is when the swimmer will be travelling the fastest (Blanksby *et al*. 2002). During the starting dive, swimmers are able to generate a large amount of power as the starting block provides a stable platform unlike water (Zatoń *et al*. 2012). Whilst the dive requires maximal effort, it is a short, single effort and therefore will have limited effect on how quickly swimmers will reach $\dot{V}O_{2max}$. Swimmers will be able to travel faster through the air and have been observed to reach distances up to 3.75 m before entering the water (Blitvich *et al*. 2000). Upon entering the water, swimmers will already be travelling faster than from a push on the wall and considerably faster than freestyle swimming therefore, providing they are able to extend into a streamlined position whilst in flight, they will be able to maintain much of this speed (Cohen *et al*. 2011). Swimmers then perform streamlined underwater fly kick. This is the most efficient method of travelling through the water and is focused on minimising deceleration; therefore one can assume that streamlined fly kick off the start will maintain a faster speed than streamlined fly kick off the turn as maximal speed is higher off the start than off the turn (Lyttle and Keys 2004). Cohen *et al*. (2011) also state that the underwater fly kick requires minimal physical exertion and therefore should have little influence of how quickly swimmers reach $\dot{V}O_{2max}$. The first 15 m of the race is the fastest section lasting between six and eight seconds (Garcia-Ramos *et al*. 2016, West *et al*. 2011), whilst the effort level is relatively low. The addition speed of the first 50 m split time can be attributed to the dive start and underwater transition rather than a high intensity swimming speed. This is in contrast to 800 m running where during the first 200 m split athletes are using large amounts of energy to accelerating up to and maintain maximal speed, which will have a significant impact on the time taken to reach severe intensity (Tucker *et al*. 2006). There is limited variation in the first 50 m split time in this study suggesting that including isolated kick practice with the intension of raising leg muscle temperature has had little or no effect on start and transitional fly kick performance.

Swimmers slow down during the middle section of the race to ensure that they are able to finish at maximum speed. Slowing down in the middle section of the race means that the intensity only reaches severe or close to $\dot{V}O_{2max}$ at the end of the race. In the present study, on average participants do not reach severe intensity until 122.95 s after the start of the performance. The effects of priming, including a speeding of $\dot{V}O_2$ kinetics by increasing the amplitude of the primary component may therefore have limited bearing on performance as the severe intensity is not reached quickly enough. *Zatoń et al.'s (2012)* study on variable velocity identifies that maintaining speed in dry land activities requires lower energy expenditure than swimming. 800 m runners are therefore able maintain effective running mechanics whilst fatiguing during the second lap which justifies their positive split race profile. 200 m swimmers will not be able to maintain effective stroke mechanics while fatiguing in the back end of the race and therefore will have to slow down during the middle section in order to ensure they finish at maximal speed. Fatiguing swimmers will have poorer stroke mechanics and for these swimmers to maintain velocity would require an increase energy expenditure which the swimmer may not be able meet and would result in a further reduction in speed. The impact of variable velocity, stroke length, stroke frequency and kick pattern on effective and efficient technique (Kolmogorov and Duplischeva 1992) require the 200 m freestyle race profile to negative split for optimal performance, thus limiting the impact of the physiological effects associated with high intensity priming activities.

5.3 Limitations

There are some limitations of the present study. First is the method of sampling; the samples consisted of anyone at the swimming club who competed at 2015 ASA South West Regional Championships and was willing to take part in the study. There was not any method of random sampling and is therefore less likely to give a true representation of the whole population. The sample size is also relatively small, only 17 participants, making it harder to distinguish any correlations between warm ups and results and therefore difficult to make any generalisations to the greater population.

This study was performed for a specific race event. Whilst participants were required to have competed in the 2015 ASA South West Regional Championships, there has been no insight into which event or events these swimmers competed at this higher level. Some of the participant may have been focused and successful on events that are contrasting to 200 m freestyle and require a different skill set, race plan and physiological profile. The researcher acknowledges that ideally this study would have only used swimmers who qualified for 200 m freestyle at the 2015 ASA South West Regional Championship in order to enhance the accuracy and validity of the findings. However, the researcher did not have access to any more participants.

All of the participants were considered to be Age Group athletes (14 years and under), however there is significant diversity across chronological age, maturity offset, stretch stature and body mass.

The test is a maximal effort test and therefore required participants to be highly motivated. Whilst the researcher provided motivation and encouragement to the athletes, it is not possible to tell whether the athletes actually completed the test with maximal effort, therefore some of the results may be inaccurate as participants may not have been fully motivated.

This study is able to suggest physiological factors that may have influenced the performance results, however it is unable to state exactly what is physiologically happening as these measurements were not taken. Neiva *et al*.'s (2016) study monitored core temperature using an ingestible temperature sensor that transmitted a radio signal to an external sensor in order to enhance the understanding of participant's physiological state before, during and after each warm up protocol and 100 m freestyle time trial. Barbosa *et al.*'s (2008) study uses a respiratory snorkel and valve system connected to a telemetric portable gas analyser to provide breath by breath gas analysis. The researcher acknowledges these methods would allow for more meaningful conclusions to be drawn from the results. These methods were not used due to the equipment and facilities available to the researcher.

To prescribe the correct pace for the intensity swims during different warm up conditions, a 50 m split time was calculated for each swimmer. The split times were monitored by the researcher and feedback was given to the swimmers during their swim. After completing their tumble turn and underwater fly kicks they were instructed to breathe to the desired side to see the researcher showing them a card stating either 'FASTER', 'SLOWER' or 'GOOD PACE'. The researcher acknowledges that this method lacks accuracy and the swimmers are not aware of how much faster or slower they need swim. The method used by Barbosa *et al.* (2008) of underwater pacemaker lights on the bottom of the pool to control swimming speed would have improved the accuracy of the prescribed intensities. This method was not used due to the equipment and facilities available to the researcher.

The author also acknowledges possible unknown variations in day to day performance due to daily events occurring outside the pool.

5.4 Recommendations

This study recommends future research should be carried out to investigate the influence of differing pacing strategies on 200 m freestyle performance to validate assumptions made by the present study on optimal race profile. Research should be conducted to assess if high intensity priming activities and isolated kick practice has any influence on performance in Youth and Senior swimmers, across different events and the impact on a full day of racing.

Also, further investigations should assess the physiological workload profile of the current negative split pacing strategy used in 200 m freestyle swimming in order to understand when swimmers are reaching their maximal workload. With an enhanced understanding of the workload, one could then conduct more in-depth research into warm up interventions that could improve performance, such as the inclusion of post-activation potentiation exercises prior to performance.

Chapter 6

Conclusion

6.1 Conclusion

The aims of the present study were (1) to compare the effects of high and low intensity warm ups on 200 m freestyle time trial results of Age Group swimmers; and (2) to compare the effects of warm ups that include and exclude an isolated kick practice on 200 m freestyle time trial results of Age Group swimmers. The results show that there is no statistical significant difference across any of the four warm up protocols that manipulate the different variables. Whilst high intensity priming exercises have been reported to make significant improvements in 800 m running (Bailey *et al*. 2009, Bailey *et al*. 2016, Ingham *et al*. 2013, Jones *et al*. 2003), this does not appear to be the case in 200 m swimming.

This study suggests that the pacing strategies employed by swimmers compared to runners accounts for this difference. Runners employ a positive split pacing strategy where the first half of the race requires a high energy output and reach the severe intensity, close to $\dot{V}O_{2max}$, near the beginning of the race and attempt to maintain the intensity for as long as possible through the duration of the race. Swimmers employ a negative split pacing strategy, where the first section of the race is performed with a lower intensity in order to conserve energy for the end of the race. This study proposes the difference in pacing strategies is due to the different levels of diminished technical ability caused by fatigue in each sport.

Whilst including isolated kick practices would suggest an increase in leg muscular temperature, thus improving performance in starts, underwater transitional fly kick and stroke efficiency, the results of this study suggest that the leg muscles are sufficiently warmed during freestyle swimming at high or low intensity. From an applied perspective, coaches might be correct in focusing their warm up protocols on performing skills with best technique rather than physiological preparedness.

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Appendix A - 2015 SW Regional Qualifying Times

ASA South West Region Qualifying Times 2015

Qualifying times to have been achieved since 1/10/14 in Licensed meets level 1, 2 or 3, and appear on ASA Ranking lists.
All times are Short Course but conversions using the ASA Equivalent Performance tables are acceptable.
Age is at 31/12/15

Time	11/12 yrs	13 yrs	14yrs	15yrs	16yrs	17yrs & over		11/12yrs	13yrs	14yrs	15yrs	16yrs	17yrs & over
Entry	32.84	30.72	28.24	27.42	26.30	24.65	50m	32.96	30.55	29.55	28.62	28.27	28.27
Consideration	33.78	31.58	29.52	28.26	27.12	25.20	Freestyle	34.08	31.57	30.35	29.36	28.88	28.88
Entry	1.13.56	1.07.54	1.01.36	59.87	56.31	54.96	100m	1.11.21	1.05.80	1.04.01	1.01.35	1.00.13	1.00.13
Consideration	1.16.31	1.10.16	1.03.96	1.01.26	58.33	55.50	Freestyle	1.14.99	1.09.06	1.05.39	1.02.84	1.02.11	1.02.11
Entry	2.32.20	2.24.42	2.12.23	2.06.59	2.01.64	1.59.00	200m	2.30.78	2.22.38	2.16.19	2.10.81	2.09.37	2.09.37
Consideration	2.37.89	2.28.83	2.16.37	2.11.30	2.05.52	2.04.00	Freestyle	2.37.36	2.24.22	2.19.24	2.13.64	2.11.15	2.11.15
Entry	5.22.78	5.06.41	4.35.94	4.24.31	4.18.77	4.12.31	400m	5.17.29	4.56.05	4.47.39	4.35.02	4.35.02	4.35.02
Consideration	5.33.80	5.14.35	4.44.58	4.33.23	4.23.72	4.15.20	Freestyle	5.26.36	5.08.71	4.51.14	4.41.29	4.41.29	4.41.29
Entry	20.50.68	20.50.68	19.22.12	18.48.44	18.47.20	17.41.00	800/1500m	11.23.49	10.22.78	9.57.32	9.28.23	9.28.23	9.28.23
Consideration	22.00.00	22.00.00	20.30.00	19.30.00	19.00.00	18.30.00	Freestyle	12.03.46	10.53.95	10.11.10	9.52.81	9.46.56	9.46.56
Entry	38.01	36.02	32.67	31.98	30.12	28.78	50m	37.90	35.06	33.85	33.08	32.03	32.03
Consideration	39.30	37.32	34.19	33.11	31.39	30.50	Backstroke	39.25	36.66	34.77	33.88	32.87	32.87
Entry	1.24.15	1.17.32	1.10.27	1.08.16	1.03.84	1.01.00	100m	1.21.53	1.15.03	1.11.86	1.08.79	1.07.88	1.07.88
Consideration	1.29.03	1.20.00	1.13.50	1.10.62	1.06.91	1.04.40	Backstroke	1.25.44	1.19.04	1.13.95	1.12.02	1.09.53	1.09.53
Entry	2.50.66	2.40.71	2.26.26	2.22.41	2.15.07	2.12.25	200m	2.47.67	2.36.87	2.33.70	2.25.05	2.23.59	2.23.59
Consideration	2.56.97	2.44.40	2.32.95	2.30.57	2.21.21	2.16.10	Backstroke	2.52.89	2.44.78	2.36.65	2.29.91	2.26.35	2.26.35
Entry	44.32	40.78	38.21	35.24	34.14	30.93	50m	43.74	40.22	38.05	37.89	36.63	36.62
Consideration	45.64	42.80	39.71	37.46	35.35	32.60	Breaststroke	45.27	41.74	39.50	38.56	38.39	38.28
Entry	1.36.47	1.30.22	1.22.15	1.15.89	1.13.17	1.07.83	100m	1.36.00	1.27.60	1.23.86	1.20.83	1.18.42	1.17.27
Consideration	1.43.26	1.35.41	1.26.43	1.20.58	1.16.32	1.13.90	Breaststroke	1.38.76	1.29.63	1.26.17	1.24.10	1.22.56	1.22.15
Entry	3.18.66	3.09.76	2.53.71	2.44.51	2.35.34	2.29.45	200m	3.17.68	3.06.14	2.55.97	2.50.72	2.46.13	2.50.72
Consideration	3.27.42	3.14.38	3.00.26	2.49.63	2.42.26	2.43.80	Breaststroke	3.27.01	3.08.79	3.02.16	2.56.64	2.56.16	2.56.16
Entry	37.69	34.96	31.81	30.45	28.80	26.71	50m	37.69	34.42	32.79	31.64	31.43	31.20
Consideration	39.06	36.68	33.63	31.55	30.21	27.50	Butterfly	39.27	35.64	33.84	32.52	32.27	32.27
Entry	1.31.81	1.20.31	1.12.35	1.07.10	1.03.83	1.00.00	100m	1.26.31	1.18.13	1.13.79	1.10.20	1.08.89	1.08.44
Consideration	1.41.48	1.25.94	1.16.73	1.11.15	1.06.99	1.01.90	Butterfly	1.33.15	1.23.89	1.17.86	1.12.66	1.12.04	1.11.96
Entry	3.12.16	2.56.89	2.41.52	2.27.70	2.21.52	2.11.06	200m	3.09.50	2.53.79	2.47.49	2.34.22	2.33.02	2.28.75
Consideration	3.28.63	3.09.77	2.51.05	2.36.76	2.29.49	2.21.30	Butterfly	3.30.22	3.09.00	2.53.84	2.42.46	2.40.68	2.40.68
Entry	2.57.66	2.48.82	2.33.39	2.26.79	2.19.21	2.15.00	200m Ind.	2.57.51	2.43.35	2.37.53	2.31.45	2.28.24	2.28.24
Consideration	3.04.65	2.53.60	2.38.53	2.31.81	2.25.72	2.25.72	Medley	3.05.22	2.51.27	2.40.32	2.36.11	2.32.30	2.32.30
Entry	6.17.80	5.52.13	2.24.46	5.05.95	4.47.83	4.47.83	400m Ind.	6.09.49	5.39.60	5.31.98	5.17.00	5.14.10	5.14.00
Consideration	6.44.36	5.58.84	5.34.00	5.15.67	5.10.40	5.10.40	Medley	6.32.45	5.47.67	5.35.20	5.25.18	5.18.63	5.18.63

Appendix B - 2015 SW Regional Warm Up Times

ASA South West Region Short Course Championships

Under ASA Laws & Regulations
President: Sue DORS
At Millfield Friday 4th, Saturday 5th & Sunday 6th November 2015
Warm-up, withdrawals and event timings.

Saturday

0845 – 0912 Men's warm-up in both pools
Plus Women's 800m relay teams
0912 – 0940 Women's warm-up in both pools

0945 Session starts
Last chance to withdraw from finals for Men is 10 minutes minutes after the start of the 400m Freestyle and 10 minutes after after the 400m finishes for Ladies
1225 Session finishes
1250 – 1330 Finals and presentations: Saturday
Present 400m Free, Swim 2, present 2, swim 3, present 3 and swim 2, present 2 to Seniors and Juniors
1330 - 1355 Break, training pool only swim down
1355 – 1440 Free warm-up in both pools
1445 Session starts
Last chance to withdraw from finals for Women is 10 minutes minutes after the start of the 400m Ind. Medley and 10 minutes after the minutes after 400m finishes for Men.
1725 Session finishes
1750 – 1830 Finals and presentations: Saturday
Present 400m IM, swim 2, present 2, swim 2 present 2 and swim 2 present 2.

Sunday

0845 – 0912 Women's warm-up in both pools
Plus Men's 800m relay teams
0912 – 0940 Men's warm-up in both pools

0945 Session starts
Last chance to withdraw from finals for Women is 10 after the start of the 400m Freestyle and 10 minutes 400m finishes for Men.
1230 Session finishes
1255 - 1335 Finals and presentations as
1335 – 1400 Break, training pool only swim
1400 – 1440 Free warm-up in both pools
1445 Session starts
Last chance to withdraw from finals for Men is 10 after the start of the 400m Ind. Medley and 10 400m finishes for Ladies
1740 Session finishes
1805– 1945 Finals and presentations as

Warm-up
Due to numbers the morning warm-up will be split, continuous swimming in both pools and sprints for last 12 minutes in competition pool. For the afternoon session it is left to coaches and swimmers to use both pools safely and as required, sprint lanes will be allocated in the competition pool when requested. The non competition end may be used at any time.

Presentations
These will be made as shown in the time table above, please ensure your swimmers are in the Presentation marshalling area when requested, suitably dressed, and that Junior's [15 years & under] who may not be in the finals are also present. Para swimmers must improve on their entry time to receive a medal when there is only one swimmer, when more the minus 1 rule will apply.

Withdrawals
Please ensure all swimmers are aware of the correct procedure and the consequences of not swimming.

REGIONAL COMPETITION DATES & VENUES 2017

ESSA Primary School Relays	27 March	Millfield Years 5/6. Final Sheffield 17/6/17
Summer Championship 15yrs & over	29/30 April, 1 May	Plymouth
Summer Championship 11/12 - 14	13/14 May	Hengrove
Summer Championship 11/12 - 14	20/21 May	Millfield
Open Water	1 July	Weymouth
Sprints [25m pool]	3 July	Gloucester
Relays [25m pool]	18 September	Millfield
ESSA Senior Relays	27 September	Millfield
Championships [Long Course]	3/4/5 November	Millfield

Event details are on the website www.swimwest.org and Sportsystems entry files will be circulated to clubs or requested from rmargetts@wcasa.co.uk and Schools events on www.essa-schoolswimming.com or Jenni Henry at HenryJ@MountKelly.com

Appendix C

Blood Lactate Concentrations from pilot study

Participant		Resting	Step 1	Step 2	Step 3	Step 4	Step 5
M1	Blood Lactate (mM)	1.2	1.3	1.6	1.8	3.7	8.9
	Time (s)		338	317	276	255	242
M2	Blood Lactate (mM)	1.7	1.3	1.0	1.2	2.0	2.8
	Time (s)		308	281	267	257	24 4
M3	Blood Lactate (mM)	Low	2.1	1.8	2.2	2.3	5.2
	Time (s)		329	286	267	261	241
M4	Blood Lactate (mM)	Low	2.2	Low	4.6	5.8	5.4
	Time (s)		288	271	261	256	259
M5	Blood Lactate (mM)	2.0	2.2	1.3	1.6	2.6	2.9
	Time (s)		307	302	274	269	254
M6	Blood Lactate (mM)	1.8	1.4	1.2	1.4	2.1	3.3
	Time (s)		324	299	283	279	262
M7	Blood Lactate (mM)	1.3	1.0	1.0	1.3	1.8	3.0
	Time (s)		297	273	267	260	246
F1	Blood Lactate (mM)	1.3	1.2	1.3	1.9	3.0	2.2
	Time (s)		280	268	253	239	227
F2	Blood Lactate (mM)	0.9	0.8	Low	Low	1.0	5.0
	Time (s)		318	304	278	247	226
Mean	Blood Lactate (mM)	1.1 ± 0.72	1.5 ± 0.53	1.0 ± 0.63	1.8 ± 1.23	2.7 ± 1.39	4.3 ± 2.09
	Time (s)		310 ± 20.3	289 ± 17.4	270 ± 9.2	258 ± 11.5	245 ± 11.2

Appendix D

Certificate Number 001458886309

Date of Issue: 16 SEPTEMBER 2014

Applicant Personal Details

Surname: RICHARDS

Forename(s): JAMES SAMUEL

Other Names: NONE DECLARED

Date of Birth: 26 FEBRUARY 1990

Place of Birth: TAUNTON

Gender: MALE

Employment Details

Position applied for:
CHILD WORKFORCE COACH

Name of Employer:
GLOUCESTER CITY SC

Countersignatory Details

Registered Person/Body:
TMGCRB

Countersignatory:
JANET HUBBARD

Police Records of Convictions, Cautions, Reprimands and Warnings

NONE RECORDED

Information from the list held under Section 142 of the Education Act 2002

NONE RECORDED

DBS Children's Barred List information

NONE RECORDED

DBS Adults' Barred List information

NOT REQUESTED

Other relevant information disclosed at the Chief Police Officer(s) discretion

NONE RECORDED

Enhanced Certificate

This document is an Enhanced Criminal Record Certificate within the meaning of sections 113B and 116 of the Police Act 1997.

THIS CERTIFICATE IS NOT EVIDENCE OF IDENTITY

Continued on page 2

DBS Disclosure and Barring Service, PO Box 165, Liverpool, L69 3JD Helpline: 0870 90 90 811

Appendix E

Participant Consent Form

Mr James Richards
Faculty of Applied Sciences
Oxstalls Campus
Oxstalls Lane
Longlevens
GLOUCESTER GL2 9HW
E: @.connect.glos.ac.uk
2014

Dear Participant,

I am inviting you to take part in a research study entitled '*An analysis of effective components for a competition warm up*'. I aim to identify the effective parts of a swimming competition warm up. I will focus on two parts of the warm up; swimming effort and the amount of kick. I will compare 200m freestyle time-trial results of different warm ups. Please read this letter and the information sheet carefully before taking part.

As part of this study, you will be asked to attend one laboratory testing session. Only measurements necessary to this research will be taken. Please see attached sheet for more information on these measurements.

You will also participate in one blood lactate testing session, where you will complete a short swim set that gets harder. After each 300m swim, your blood will be tested, a process which may be repeated a maximum of 5 times. I will take one drop of blood by a pin prick in the end of your finger which is almost painless. When the blood tests show that you are swimming at the correct effort level the test will stop.

Finally, you will also be asked to undertake four swim testing sessions. During these swim sessions, you will complete a warm up followed by a maximum effort 200m freestyle time-trial. Your parent or guardian will be able to be present during all of these testing sessions.

It is your choice whether you take part or not. Whether you agree to take part or not and the results of this research will not affect your progression through the club, squad movements or team selection. Gloucester City Swimming Club's Coaching Team will be made aware of the study's outcome. They will not have access to your individual data.

Your participation in this study could assist coaches to:

- Gain a greater understanding of successful warm ups
- Give you better warm ups that enhance your body's preparation for competitive performance
- Improve your overall swimming performance

Yours sincerely

James Richards
Email: s1008883@.connect.glos.ac.uk

Appendix F

Parent/guardian Consent Form

Mr James Richards
Faculty of Applied Sciences
Oxstalls Campus
Oxstalls Lane
Longlevens
GLOUCESTER GL2 9HW
E:
s1008883@.connect.glos.ac.uk
2014

Dear Parent/Guardian,

I would like to invite your child to volunteer to take part in a research study entitled '*An analysis of effective components for a competition warm up*'. This study will focus on two aspects for the warm up; the effects of intensity and the inclusion of kick exercises. The study will compare 200m freestyle time-trial results with different warm ups.

It is important that you understand that your child's participation/non-participation, and the results of the research will have no impact on their progression through the club, squad movements or team selection. Gloucester City Swimming Club's Coaching Team will be made aware of the study's outcome however they will not have access to any individual's data.

Your child will be asked to attend one laboratory testing session. You will be asked to stay and supervise the session. Only body measurements necessary to the research will be taken e.g. measurements of overall body size, skeletal breadths, girths and skinfold thickness. Please see attached sheet for measurement sites.

Your child will also complete one blood lactate testing session. A blood sample will be taken after each swimming interval from the tip of your child's finger. This will be carried out with a safety lancet which will cause a relatively painless pin prick in the skin to draw one drop of blood. Finally your child will undertake four swim testing sessions where they will complete a set warm up followed by a maximum effort 200m freestyle time-trial.

Your child's participation in this study could assist coaches to:

- Gain a greater understanding of the mechanisms involved in successful warm ups
- Apply best practise during warm ups to enhance the body's preparation
- Improve athletic performance

Yours sincerely

James Richards

Email: s1008883@.connect.glos.ac.uk

Appendix G

Health Questionnaire - Participant

SPORT & EXERCISE LABORATORIES

Health Questionnaire

About this questionnaire:
The purpose of this questionnaire is to gather information about your health and lifestyle. We will use this information to decide whether you are eligible to take part in the testing for which you have volunteered. It is important that you answer the questions truthfully. The information you give will be treated in confidence. Your completed form will be stored securely for 5 years and then destroyed.

Section 1, which has been completed by the tester, provides basic information about the testing for which you have volunteered. Sections 2 to 7 are for you to complete: please circle the appropriate response or write your answer in the space provided. Please also complete section 8. Sections 9 and 10 will be completed by the tester, after you have completed sections 2 to 8.

Section 1: The testing (completed by tester)

To complete the testing for which you have volunteered you will be required to undertake:

Moderate exercise (i.e., exercise that makes you breathe more heavily than you do at rest but not so heavily that you are unable to maintain a conversation)	
Vigorous exercise (i.e., exercise that makes you breath so heavily that you are unable to maintain a conversation)	X

The testing involves:

Walking		Generating or absorbing high forces through your arms	X
Running		Generating or absorbing high forces through your shoulders	X
Cycling		Generating or absorbing high forces through your trunk	X
Rowing		Generating or absorbing high forces through your hips	X
Swimming	X	Generating or absorbing high forces through your legs	X
Jumping			

Section 2: General information

Name: ……………………………………………………… Sex: M F Age:

Height (approx.): ………………………………… Weight (approx.):

Section 3: Initial considerations

1. Do any of the following apply to you? No Yes

a) I have HIV, Hepatitis A, Hepatitis B or Hepatitis C
b) I am pregnant
c)I have a muscle or joint problem that could be aggravated by the testing described in section 1
d) I am feeling unwell today

e) I have had a fever in the last 7 days

(If you have answered "Yes" to question 1, go straight to section 8)

Section 4: Habitual physical activity

2a. Do you typically perform moderate exercise (as defined in section 1) for 20 minutes or longer at least twice a week? No Yes

2b. Have you performed this type of exercise within the last 10 days? No Yes

3a. Do you typically perform vigorous exercise (as defined in section 1) at least once a week? No Yes

3b. Have you performed this type of exercise within the last 10 days? No Yes

Section 5: Known medical conditions

4. Does the following apply to you? No Yes

   a) I have had Type 1 diabetes for more than 15 years

5. Have you ever had a stroke? No Yes

6. Has your doctor ever said you have heart trouble? No Yes

7. Do **both** of the following apply to you? No Yes

   a) I take asthma medication
   b) I have experienced shortness of breath or difficulty with breathing in the last 4 weeks? No Yes

8. Do you have any of the following: cancer, COPD, cystic fibrosis, other lung disease, liver disease, kidney disease, mental illness, osteoporosis, severe arthritis, a thyroid problem? No Yes

(If you have answered "Yes" to any questions in section 5, go straight to section 8.)

Section 6: Signs and symptoms

9. Do you often have pains in your heart, chest, or the surrounding areas? No Yes

10. Do you experience shortness of breath, either at rest or with mild exertion? No Yes

11. Do you often feel faint or have spells of severe dizziness? No Yes

12. Have you, in the last 12 months, experienced difficulty with breathing when lying down or been awakened at night by shortness of breath? No Yes

13. Do you experience swelling or a build up of fluid in or around your ankles? No Yes

14. Do you often get the feeling that your heart is racing or skipping beats, either at rest or during exercise? No Yes

15. Do you regularly get pains in your calves and lower legs during exercise that are not due to soreness or stiffness? No Yes

16. Has your doctor ever told you that you have a heart murmur? No Yes

17. Do you experience unusual fatigue or shortness of breath during everyday activities? No Yes

(If you have answered "Yes" to any questions in section 6, go straight to section 8.)

Section 7: Risk factors

18. Does **either** of the following apply to you? No Yes

   a) I smoke cigarettes on a daily basis
   b) I stopped smoking cigarettes on a daily basis less than 6 months ago

19. Has your doctor ever told you that you have high blood pressure? No Yes

20. Has your doctor ever told you that you have high cholesterol? No Yes

21. Has your father or any of your brothers had a heart attack, heart surgery, or a stroke before the age of 55? No Yes

22. Has your mother or any of your sisters had a heart attack, heart surgery, or a stroke before the age of 65? No Yes

23. Do **any** of the following apply to you? No Yes

   a) I have had Type 1 diabetes for less than 15 years
   b) I have Type 1 diabetes and am 30 or younger
   c) I have Type 2 diabetes and am 35 or younger

Section 8: Signatures

Participant (Print & Sign): ……………………………………………………..

Date: ......……………..

Section 9: Additional risk factors (to be completed by the tester if relevant)

24. Is the participant's body mass index >30 kg/m^2? No Yes

25. Has the participant answered no to questions 2a **and** 3a? No Yes

Section 10: Eligibility (to be completed by the tester)

26. Is the participant eligible for the testing? No Yes

Name (of tester): ....…………...........……………………

Signature: ………………………………………………… Date: …………....……………...

Appendix H

Health Questionnaire - Parent

SPORT & EXERCISE LABORATORIES

Parent/ Guardian Health Questionnaire

About this questionnaire:
The purpose of this questionnaire is to gather information about your health and lifestyle history. The researcher will use this information to decide whether your son is eligible to take part in the testing for which they have volunteered. It is important that you answer the questions truthfully. The information you give will be treated in confidence. Your completed form will be stored securely for 5 years and then destroyed.

Section One, which has been completed by the tester, provides basic information about the testing for which your son has volunteered. Sections Two to Four are for you (the parent/ guardian) to complete: Please circle the appropriate response or write your answer in the space provided. Sections Five and Six will be completed by the tester thereafter.

Section One: The testing (completed by tester)

To complete the testing for which you have volunteered you will be required to undertake:

Moderate exercise (i.e., exercise that makes you breathe more heavily than you do at rest but not so heavily that you are unable to maintain a conversation)	
Vigorous exercise (i.e., exercise that makes you breath so heavily that you are unable to maintain a conversation)	X

The testing involves:

Walking		Generating or absorbing high forces through your arms	X
Running		Generating or absorbing high forces through your shoulders	X
Cycling		Generating or absorbing high forces through your trunk	X
Rowing		Generating or absorbing high forces through your hips	X
Swimming	X	Generating or absorbing high forces through your legs	X
Jumping			

Section 2: General information

Name: .... Sex: M F Age:

Height (approx.): .... Weight (approx.):

Section One: Initial considerations

2. Do any of the following apply to your son? No Yes
   a) HIV, Hepatitis A, Hepatitis B or Hepatitis C
   b) A muscle or joint problem that could be aggravated by the testing described in section 1
   c) They have had a fever in the last 7 days

(If you have answered "Yes" to question 1, go straight to section 8)

Section Two: Known medical conditions

2. Does the following apply to your son? No Yes
   b) Type 1 diabetes for more than 15 years

3. Have they ever had a stroke? No Yes

4. Has their doctor ever said your son has had heart trouble? No Yes

5. Do **both** of the following apply to your son? No Yes
   a) They take asthma medication
   b) Have experienced shortness of breath or difficulty with breathing in the last 4 weeks? No Yes

6. Does your son have any of the following: cancer, COPD, cystic fibrosis, Other lung disease, liver disease, kidney disease, mental illness, Osteoporosis, severe arthritis, a thyroid problem? No Yes

(If you have answered "Yes" to any questions in section 5, go straight to section 8.)

Section Three: Risk factors

7. Has your doctor ever told you that high blood pressure? No Yes

8. Has your doctor ever told you that your son has high cholesterol? No Yes

9. Have you as your son's father/ mother and any of your son's uncles/ aunties had a heart attack, heart surgery, or a stroke before the age of 55 (for males) or 65 (for females)? No Yes

10. Do **any** of the following apply to your son? No Yes
    a) My son has had Type 1 diabetes for less than 15 years
    b) My son has had Type 1 diabetes and am 30 or younger
    c) My son has had Type 2 diabetes and am 35 or younger

Section Four: Declaration and Signatures

To the best of my knowledge my son is healthy and able to participate in the proposed research study activities described in 'Section One: Testing'.

Parent/ Guardian (Print & Sign): ……………………………………………………..

Date: ......……………...

Section Five: Additional risk factors (to be completed by the tester if relevant)

24. Is the participant's body mass index >30 kg/m^2? No Yes

25. Has the participant answered no to questions 2a **and** 3a? No Yes

Section Six: Eligibility (to be completed by the tester)

26. Is the participant eligible for the testing? No Yes

Name (of tester): ....…………..........……………………

Signature: ………………………………………………… Date: ………...….……….…..

Appendix I

Land Warm Up Activities

6 x lying T rotations

6 x seated upper body rotations

6 x 135° groin stretch

4 x gorilla squat into chameleon

2 x gorilla squat in to hip extension patterns – left, right, toe press, free fall

6 x spiderman

4 x floor angels

4 x wall angels

Appendix J

Equations

(Eq1) MAS = 400 m/ 300 s = 1.33 m.s^{-1}

(Eq2) LI = 1.33 m.s^{-1}/ 100 x 70 = 0.931 m.s^{-1}

50 m / 0.931 m.s^{-1}= 53.70 s per 50 m split

(Eq3) HI = 1.33 m.s^{-1}/ 100 x 90 = 1.197 m.s^{-1}

50 m / 1.197 m.s^{-1}= 41.77 s per 50 m split

Appendix K

University of Gloucestershire's Research Ethics Committee Approval

Dear James

I am slightly embarrassed to have found a half written reply in my drafts folder (but ticked off my to-do list) so it with abject apologies that I send this note.

I have reviewed the attached information and am happy to confirm that it addresses the issues we discussed at RESC. Please forward a copy of your DBS certificate to Sharon Brookshaw.

Given this, I am happy to confirm that the project is approved by RESC and wish you all the best with it.

Best wishes

Malcolm MacLean
Chair – Research Ethics Sub-Committee

Dr Malcolm MacLean
Associate Dean Quality & Standards
Reader in the Culture and History of Sport
Faculty of Applied Sciences
University of Gloucestershire
Oxstalls Lane
Gloucester GL2 9HW
England
'The majority by their silence will pay for days like these' Billy Bragg

Emily Ryall, Wendy Russell & Malcolm MacLean (eds) *The Philosophy of Play*, Routledge
See **http://www.routledge.com/books/details/9780415538350/**

MM

Appendix L

Risk Assessment

Possible Hazards	Severity (without control measures)	Persons exposed (employees, students etc	Risk Control Measures Currently in place	Likelihood (with control measures)	Risk Level	Action Required	Action Completed (date and signature)
							05/02/2014
							05/02/2014
							05/02/2014
							05/02/2014
							05/02/2014
							05/02/2014
							05/02/2014
Needle Stick injury	low	Participants	Wear PPE and work slowly and carefully. The lancets for finger pricks are designed in such a way that they can only	Unlikely	low	None	05/02/2014

			be used once, thereby minimising the possibility of cross contamination.				
Fainting	low	Participants	Stop test. Lie the patient down and stay with them until they have recovered. Little sips of water and a wet towel applied to the forehead. Verbal communication throughout the procedure will reassure the subject.	Unlikely	low	None	05/02/2014
Haematoma	medium	Participants	Follow correct collection procedures, if unable to draw blood, withdraw the needle and apply light pressure to the site. Do not attempt to withdraw blood at the same site again	Unlikely	low	None	05/02/2014

Appendix M

SPSS Output

General Linear Model

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
	Pillai's Trace	.137	2.534[b]	1.000	16.000	.131	.137	2.534	.322
	Wilks' Lambda	.863	2.534[b]	1.000	16.000	.131	.137	2.534	.322
	Hotelling's Trace	.158	2.534[b]	1.000	16.000	.131	.137	2.534	.322
	Roy's Largest Root	.158	2.534[b]	1.000	16.000	.131	.137	2.534	.322
	Pillai's Trace	.010	.163[b]	1.000	16.000	.692	.010	.163	.067
	Wilks' Lambda	.990	.163[b]	1.000	16.000	.692	.010	.163	.067
	Hotelling's Trace	.010	.163[b]	1.000	16.000	.692	.010	.163	.067
	Roy's Largest Root	.010	.163[b]	1.000	16.000	.692	.010	.163	.067
	Pillai's Trace	.114	2.052[b]	1.000	16.000	.171	.114	2.052	.270
	Wilks' Lambda	.886	2.052[b]	1.000	16.000	.171	.114	2.052	.270
	Hotelling's Trace	.128	2.052[b]	1.000	16.000	.171	.114	2.052	.270
	Roy's Largest Root	.128	2.052[b]	1.000	16.000	.171	.114	2.052	.270

a. Design: Intercept
 Within Subjects Design: Intensity + Kick + Intensity * Kick

b. Exact statistic

c. Computed using alpha = .05

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

					Epsilon[b]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Intensity	1.000	.000	0	.	1.000	1.000	1.000
Kick	1.000	.000	0	.	1.000	1.000	1.000
Intensity * Kick	1.000	.000	0	.	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: Intensity + Kick + Intensity * Kick

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
	Sphericity Assumed	26.040	1	26.040	2.534	.131	.137	2.534	.322
	Greenhouse-Geisser	26.040	1.000	26.040	2.534	.131	.137	2.534	.322
	Huynh-Feldt	26.040	1.000	26.040	2.534	.131	.137	2.534	.322
	Lower-bound	26.040	1.000	26.040	2.534	.131	.137	2.534	.322
	Sphericity Assumed	164.406	16	10.275					
	Greenhouse-Geisser	164.406	16.000	10.275					

	Huynh-Feldt	164.406	16.000	10.275					
	Lower-bound	164.406	16.000	10.275					
	Sphericity Assumed	2.455	1	2.455	.163	.692	.010	.163	.067
	Greenhouse-Geisser	2.455	1.000	2.455	.163	.692	.010	.163	.067
	Huynh-Feldt	2.455	1.000	2.455	.163	.692	.010	.163	.067
	Lower-bound	2.455	1.000	2.455	.163	.692	.010	.163	.067
	Sphericity Assumed	241.385	16	15.087					
	Greenhouse-Geisser	241.385	16.000	15.087					
	Huynh-Feldt	241.385	16.000	15.087					
	Lower-bound	241.385	16.000	15.087					
	Sphericity Assumed	23.459	1	23.459	2.052	.171	.114	2.052	.270
	Greenhouse-Geisser	23.459	1.000	23.459	2.052	.171	.114	2.052	.270
	Huynh-Feldt	23.459	1.000	23.459	2.052	.171	.114	2.052	.270
	Lower-bound	23.459	1.000	23.459	2.052	.171	.114	2.052	.270
	Sphericity Assumed	182.954	16	11.435					
	Greenhouse-Geisser	182.954	16.000	11.435					
	Huynh-Feldt	182.954	16.000	11.435					
	Lower-bound	182.954	16.000	11.435					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Intensity	Kick	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intensity	Linear		26.040	1	26.040	2.534	.131	.137	2.534	.322
Error(Intensity)	Linear		164.406	16	10.275					
Kick		Linear	2.455	1	2.455	.163	.692	.010	.163	.067
Error(Kick)		Linear	241.385	16	15.087					
Intensity * Kick	Linear	Linear	23.459	1	23.459	2.052	.171	.114	2.052	.270
Error(Intensity*Kick)	Linear	Linear	182.954	16	11.435					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	1845911.726	1	1845911.726	1868.195	.000	.992	1868.195	1.000
Error	15809.155	16	988.072					

a. Computed using alpha = .05

Within-Subjects Factors

Measure: MEASURE_1

Condition	distance	Dependent Variable
	1	LI50
	2	LI100
	3	LI150
	4	LI200
	1	LIK50
	2	LIK100
	3	LIK150
	4	LIK200
	1	HI50
	2	HI100
	3	HI150
	4	HI200
	1	HIK50
	2	HIK100
	3	HIK150
	4	HIK200

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
	Pillai's Trace	.099	.515[b]	3.000	14.000	.678	.099	1.546	.129
	Wilks' Lambda	.901	.515[b]	3.000	14.000	.678	.099	1.546	.129
	Hotelling's Trace	.110	.515[b]	3.000	14.000	.678	.099	1.546	.129
	Roy's Largest Root	.110	.515[b]	3.000	14.000	.678	.099	1.546	.129
	Pillai's Trace	.951	89.849[b]	3.000	14.000	.000	.951	269.547	1.000
	Wilks' Lambda	.049	89.849[b]	3.000	14.000	.000	.951	269.547	1.000
	Hotelling's Trace	19.253	89.849[b]	3.000	14.000	.000	.951	269.547	1.000
	Roy's Largest Root	19.253	89.849[b]	3.000	14.000	.000	.951	269.547	1.000
	Pillai's Trace	.812	3.840[b]	9.000	8.000	.036	.812	34.558	.765
	Wilks' Lambda	.188	3.840[b]	9.000	8.000	.036	.812	34.558	.765
	Hotelling's Trace	4.320	3.840[b]	9.000	8.000	.036	.812	34.558	.765
	Roy's Largest Root	4.320	3.840[b]	9.000	8.000	.036	.812	34.558	.765

a. Design: Intercept
Within Subjects Design: Condition + distance + Condition * distance

b. Exact statistic

c. Computed using alpha = .05

Mauchly's Test of Sphericity[a]

Measure: MEASURE_1

					Epsilon[b]

		Square			Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Condition	.846	2.468	5	.782	.892	1.000	.333
distance	.445	11.933	5	.036	.708	.819	.333
Condition * distance	.000	99.836	44	.000	.429	.582	.111

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. Design: Intercept

Within Subjects Design: Condition + distance + Condition * distance

b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
	Sphericity Assumed	2.694	3	.898	.475	.701	.029	1.426	.139
	Greenhouse-Geisser	2.694	2.677	1.006	.475	.680	.029	1.273	.133
	Huynh-Feldt	2.694	3.000	.898	.475	.701	.029	1.426	.139
	Lower-bound	2.694	1.000	2.694	.475	.500	.029	.475	.099
	Sphericity Assumed	90.673	48	1.889					
	Greenhouse-Geisser	90.673	42.833	2.117					
	Huynh-Feldt	90.673	48.000	1.889					
	Lower-bound	90.673	16.000	5.667					
	Sphericity Assumed	1855.019	3	618.340	151.599	.000	.905	454.797	1.000
	Greenhouse-Geisser	1855.019	2.123	873.716	151.599	.000	.905	321.865	1.000

	Huynh-Feldt	1855.019	2.457	755.041	151.599	.000	.905	372.455	1.000
	Lower-bound	1855.019	1.000	1855.019	151.599	.000	.905	151.599	1.000
	Sphericity Assumed	195.782	48	4.079					
	Greenhouse-Geisser	195.782	33.970	5.763					
	Huynh-Feldt	195.782	39.310	4.981					
	Lower-bound	195.782	16.000	12.236					
	Sphericity Assumed	2.638	9	.293	.483	.884	.029	4.350	.231
	Greenhouse-Geisser	2.638	3.859	.684	.483	.741	.029	1.865	.155
	Huynh-Feldt	2.638	5.239	.504	.483	.796	.029	2.532	.177
	Lower-bound	2.638	1.000	2.638	.483	.497	.029	.483	.100
	Sphericity Assumed	87.334	144	.606					
	Greenhouse-Geisser	87.334	61.743	1.414					
	Huynh-Feldt	87.334	83.817	1.042					
	Lower-bound	87.334	16.000	5.458					

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	Condition	distance	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
	Linear		1.044	1	1.044	.402	.535	.025	.402	.092
	Quadratic		.773	1	.773	.500	.490	.030	.500	.102
	Cubic		.877	1	.877	.574	.460	.035	.574	.110
	Linear		41.510	16	2.594					
	Quadratic		24.728	16	1.546					
	Cubic		24.436	16	1.527					

distance	Linear	971.074	1	971.074	140.601	.000	.898	140.601	1.000
	Quadratic	882.721	1	882.721	220.667	.000	.932	220.667	1.000
	Cubic	1.224	1	1.224	.921	.352	.054	.921	.147
	Linear	110.505	16	6.907					
	Quadratic	64.004	16	4.000					
	Cubic	21.273	16	1.330					
	Linear	.378	1	.378	.323	.578	.020	.323	.083
	Quadratic	.080	1	.080	.097	.759	.006	.097	.060
	Cubic	.004	1	.004	.017	.897	.001	.017	.052
	Linear	.121	1	.121	.086	.773	.005	.086	.059
	Quadratic	.065	1	.065	.087	.771	.005	.087	.059
	Cubic	.354	1	.354	1.516	.236	.087	1.516	.212
	Linear	.798	1	.798	2.893	.108	.153	2.893	.359
	Quadratic	.295	1	.295	1.496	.239	.085	1.496	.210
	Cubic	.543	1	.543	1.549	.231	.088	1.549	.216
	Linear	18.697	16	1.169					
	Quadratic	13.159	16	.822					
	Cubic	4.025	16	.252					
	Linear	22.564	16	1.410					
	Quadratic	11.976	16	.748					
	Cubic	3.735	16	.233					
	Linear	4.413	16	.276					
	Quadratic	3.153	16	.197					
	Cubic	5.611	16	.351					

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1

Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Intercept	462620.423	1	462620.423	1973.102	.000	.992	1973.102	1.000
Error	3751.417	16	234.464					

a. Computed using alpha = .05