To Investigated whether a low intensity swim or a low intensity swim with high intensity bursts was more effective in allowing swimmers to return to baseline levels following a simulated swim race.

Waterford Institute of Technology

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A project submitted in part fulfilment of the requirement for the BSc in Sports Coaching and Performance

Declaration

Statement of originality and ownership of work

Department of Health, Sport and Exercise and Science BSc in Sports Coaching and Performance

Name (block capitals)..

I confirm that all the work submitted in this project is my own work, not copied from any other person's work (published or unpublished) and that it has not previously been submitted for assessment on any other course, in any other institution.

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Abstract:

The purpose of the present study was to test the effectiveness of two swimming recovery protocols on the removal on lactate after a 200m race paced swim. Twelve swimmers from the NAC swim team were tested. The swimmers were randomly assigned a recovery protocol, with 6 athletes carrying out a high velocity overload recovery and 6 of the athletes carrying out a steady state recovery protocol. Blood lactate, Heart rate and Rate of perceived exertion (RPE) was measured in the athlete after the warm up, race paced swim and after the recovery protocol. Lactate was used to measure the effectiveness of the recovery protocol by measuring the physiological response to exercise. Heart rate and RPE was used to show the effect the exercise stage had on the group. There was no significant difference between the lactate, heart and RPE in any of the groups at any stage. Both groups significantly decreased in lactate from after the race paced swim to after each of the recovery protocols.

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Introduction:

Swimming is a demanding sport requiring athletes to be involved in multiple races in a single day (Hinzpeter, Zamorano, Cuzmar, Lopez & Burboa, 2014). During competition, swimmers often have short rest periods between races, sometimes only getting as little as 10 minutes to recover, which highlights the importance of finding an optimal recovery (Greenwood et al, 2008). Many recovery protocols are apparent in the literature, with a low intensity swim commonly reported (Neric, Beam, Brown and Wiersma, 2009; Mota et al, 2008). More often in practice, a low intensity swim with high intensity bursts (high velocity overload) is utilized however limited evidence exists detailing its effectiveness. The aim of this study is to investigate whether a low intensity swim or a low intensity swim with high intensity bursts is more effective in allowing swimmers to return to baseline levels following a simulated swim race.

Demands of competitive swimming:

Swimming is a physically demanding sport that requires athletes to have elements of power, speed and endurance (Pyne & Sharp, 2014), requiring both upper and lower body power (Hawley, 1992). There are four main strokes in swimming including freestyle, backstroke, breaststroke and butterfly, which all differ in terms of energy requirements. The energy systems used in swimming events are a combination of the aerobic, lactate and ATP system, which change in relation to stroke type and the distance covered (Pyne & Sharp, 2014), while the additional resistance of drag also needs to be taking into account (Troup, 1999). The large number of biomechanical and physiological demands of swimming have a huge impact on the success of athletes (Troup, 1999), which highlights the importance of the athlete returning to a baseline physiological level when competing again after recovery. These are usually similar distances, but different strokes and athletes can choose whether they want to compete in long or short distance races (Swim Meet Terminology, 2019). The distances range from 50m to 1500m (Rodríguez & Mader, 2011), with many studies focusing on a 200m swim (lomax, 2012, Mota et al 2008), as it is one of the shorter intensity swims that are carried out in competitions. For a 200m freestyle swim, there are a large number of demands, which requires the use anaerobic glycolytic energy system (Rodríguez & Mader, 2011). The typical time to complete a 200m freestyle race paced swim varies with the world record time for a 200m freestyle swim being 1:42 seconds which is held by Michael Phelps whereas amateur record can be up to 3 minutes (The Swimming Expert, 2019).

Competitive swimming:

Swimming is one of the few sports in which athletes compete across different distances and with different techniques during competitions (Stewart & Hopkins, 2000). The aim of a swimming competition is to cover a given distance in the shortest amount of time (Saavedra, 2012). During swimming competitions, athletes have to compete in multiple races at maximal level, which may affect their performance in their final race (Hinzpeter, Zamorano, Cuzmar, Lopez, & Burboa, 2014). Swimmers compete in multiple races of varying strokes and lengths which requires them to be involved in multiple warm ups, multiple race paced swims and multiple cool downs in a single day of competition (Neric et al, 2009) . At swimming competitions athletes typically compete in 3-4 different races. An example of a typical day at a swimming competition for an athlete could involve competing in 3 heats in the morning and competing in 3 finals then in the afternoon. In some cases athletes only have minutes between their heats (Greenwood et al, 2008). Depending on the times of each race, it could require the athlete to carry out six warm ups and six cool downs. The athletes will need to be returned to baseline physiological levels to prepare to compete again if successful in moving to another stage or in another swim event (Neric et al, 2009). In swim competitions a swim down pool is usually available for athletes to use for their warm up and recovery session after their swim, in the case when a swim down pool is not available athletes would have to implement their land based warm ups and cool downs (Lomax, 2012).

Importance of recovery:

It is assumed that perfecting a recovery protocol will allow athletes to perform better during subsequent training and competitions (Hooren and Peake, 2018). This is fitting as the aim of recovery during swim competitions is to be fully recovered for the next swim and that the previous swim would not impact the athletes performance. Swimming is different to most sports as athletes have to compete across multiple races in one day (Casuso, 2014). Ideally athletes would be fully recovered before they have to compete again (Neric et al, 2009), however strenuous physical exercise can lead to fatigue in athletes which causes a decrease in performance (Hinzpeter, Zamorano, Cuzmar, Lopez & Burboa, 2014). The role of a recovery protocol is to return athletes from a fatigued state back to their baseline level (Rezaee, Esfarjani, & Marandi, 2012), with a cool down being typically used as a method of recovery (Lomaz, 2012). Having a cool down in place can help relieve the physical tensions created by a competition (Karvonen, 1992), which includes higher lactate levels, increased heart rate and fatigue (Rezaee, Esfarjani, & Marandi, 2012). If an athlete is not fully recovered after a previous swim race their next race could be negatively affected (Neric et al, 2009). Athletes lactate levels would not be returned to baseline, and an elevated pre-swim lactate level has been shown to have a direct adverse effect on performance (Lomax,2012). The typical recoveries considered are chronic recovery strategies which are carried out over hours to days, such as nutrition and rest (Kinugasa, & Kilding, 2009). In swimming immediate recovery strategies have to be considered as the athletes may have as little as 10 minutes before they have to compete again (Greenwood et al, 2008). Researchers have attempted to find the optimal recovery protocol by testing many different types of recovery including active or passive recovery and water or land based recoveries (Lomax, 2012; Mota et al., 2017; Neric, Beam, Brown and Wiersma, 2009 Hinzpeter, 2014).

Typical Markers of recovery:

There are many markers of recovery that can be used in order to assess whether an athlete is fully recovered (Djaoui, Haddad, Chamari, & Dellal, 2017). Some typically used markers are blood testing (lactate, haematocrit, and an athlete's iron status), urine testing, hormone testing, heart rate monitoring and monitoring rate of perceived exertion. During testing, the tester will select a number of markers based on what they are attempting to measure (Djaoui, Haddad, Chamari, & Dellal, 2017), with lactate, heart rate and RPE being the most common and convenient measurements used (Lomax , 2012).

Lactate:

The assessment of blood lactate is used in an attempt to get a better understanding of the recovery process and has been used for numerous years for monitoring exercise intensity (Stavrianeas & Stephenson, 2007). Blood lactate is one of the most often measured variables in exercise testing (Goodwin, Harris, Hernández, & Gladden, 2007). The rate at which lactate is removed from the blood has been used as an objective measure of recovery (Van Hooren, & Peake, 2018) and it is a key step in understanding the bodies physiological response to exercise (Adeva-Andany et al, 2015). Accumulation of lactate in swimmers during competition is common due to athletes being involved in multiple high bouts of exercise (Neric, Beam, Brown & Wiersma 2009). Adeva- Andany et al (2015) explains that Lactate is a biproduct of glucose or alanine through the conversion into pyruvate. Lactate accumulates when pyruvate formation exceeds pyruvate oxidation. During exercise, lactate and hydrogen ions accumulate in contracting muscles (Juel et al, 2004). The associated hydrogen ions negatively affect performance in swimmers due to the adverse effect it has on the central nervous system resulting in a decrease in the velocity when moving through water (Pupisová, Pupis, & Pivovarnicek, 2015), therefore it is important after and during exercise to reduce the levels of lactate (Menzies, 2010). Lactate is typically measured 3 minutes after exercise to ensure the blood value is at its peak (Goodwin, Harris, Hernández, & Gladden 2007). When measuring lactate a sample of blood is taken from athletes fingertip or ear lobe and is analysed using a lactate monitor. A Lactate pro is a type of handheld, battery powered, lactate monitor, which is easy to use and only requires a small blood sample to be taken from an athlete's fingertip in order to assess lactate levels (McLean, Norris, & Smith, 2004). The time at which lactate returns to baseline levels is dependent on the type of recovery which is under taken (Menzies et al 2010). Menzies's (2010) study showed that lactate cleared faster at 60-100% of the lactate threshold rather than the lower intensity of 0-40% of the lactate threshold. Participants of the study carried out recoveries at 100%, 80%, 60%, 40% or 0% of their lactate threshold to find which was the most effective. The athletes lactate and heart rate were recorded throughout the study as measures for exercise intensity. One downfall to this study was that it was carried out on a treadmill so results may vary in a swimming pool.

Heart Rate:

Heart rate changes coincide with exercise intensity; when exercise intensity increases, heart rate increases, when exercise intensity decreases heart rate decreases (Daanen et al, 2012). Athletes with a better cardiovascular fitness may have a lower resting heart rate and their heart rate may return to baseline levels faster than those who are not as fit ("Improve Heart Health by Knowing Your Recovery Heart Rate", 2013). After an intense bout of exercise athletes will see a large rise in heart rate (Meshkati, 1988). Trained athletes have been seen to have accelerated heart rate reduction after exercise (Borresen and Lambert, 2008). Heart rate can be measured by having heart rate monitors worn around the chests of the athletes. Heart rate should not be used alone as a measure but is sufficient when used with other measures (Daanen et al, 2012). Heart rate is considered one of the most reliable measures of workload as it is constantly available from all athletes (Meshkati, 1988) and is an easy accessible monitoring tool (Schönfelder, Hinterseher, Peter, & Spitzenpfeil, 2011).

Rate of perceived exertion (RPE):

RPE is how hard an athlete perceives a bout of physical activity to be (Borg, 1982), with the chart increasing linearly with the rate of exercise intensity. The values range from 6 – 20, with 6 being no exertion at all and 20 being maximal exertion. Appendix 1 shows the typical Borg RPE scale which is used with athletes. The scale is usually held in front of athletes and they either call out a number or give a signal when somebody calls the number that they feel they are at. RPE scale is an easy accessible and inexpensive measure of exercise intensity but the disadvantages of RPE is that it is subjective, as athletes would have to be efficient in using the scale for it to be effective and valid (Ciolac, 2015). Rate of perceived scale is made to increase exponentially with increasing power and heart rate. It works alongside heart rate and gives how hard the athletes themselves perceived the exercise bout to be which is why it is a good marker of recovery (Borg, Ljunggren, and Ceci, 1985).

Common Methods of Recovery:

Various recovery methods are used to facilitate recovery in athletes after exercise (Van Hooren, & Peake, 2018). The types of recovery used can vary from athlete to athlete. Common recovery strategies in swimming are active or passive recoveries and land or water based recoveries.

Active vs passive recovery:

Many papers assess whether an active or passive recovery is the more effective in enhancing recovering through assessing blood lactate (Hinzpeter et al, 2014; Greenwood et al. 2008; Mota et al. 2017; Neric et al. 2009). Passive recovery is a non-active recovery protocol, usually involving athletes sitting for a period of time (Weltman, Stamford, Moffatt, & Katch, 1977). An active recovery is a recovery where athletes perform an exercise protocol at any intensity higher than rest (Taoutaou et al, 1996), an example would be steady state swimming. In cases such as Lomax et al (2012) and Neric et al (2009), it is perceived that an active recovery may be more effective than a passive. At some swimming competitions, athletes do not always have access to a swimming pool for a cool down which means they would have to carry out a passive recovery. Mota et al (2017) investigated whether an active or passive recovery was more effective in enhancing recovering through assessing blood lactate levels. The investigation required

14 high performance athletes (7 males aged 17.71 ±1.25 years and 7 females aged 18.29±1.6 years) to participate in a 200m freestyle race paced swim followed by one of the following recovery protocols; one recovery was 5 minutes of passive recovery followed by 10 minutes of an active, self-prescribed, water-based recovery and the second was 15 minutes of passive recovery. The self-prescribed recovery involved athletes swimming for 10 minutes, with no coaching and no prescribed workout. The passive recovery required athletes to lie down covered on a towel for 15 minutes. The athletes velocity was calculated by using a ratio of the distance that they had covered to the time spent swimming. It was found that the athletes swam at an average velocity of 69% of their maximum. The study reports that an active recovery was more effective in removing lactate and returning to baseline values in swim athletes. Blood lactate levels in the passive recovery group was 1.76 ± 1.70 mmol L^{-1} whereas in the active recovery it was 4.30 ± 1.74 mmol L^{-1}. The study uses a self-prescribed swim for the active recovery, this is a weakness of the study as all the swimmers could be swimming at completely different velocities which makes the recovery difficult to replicate. Similarly, Hinzpeter et al (2014) reported that active recovery is more effective than a passive recovery in removing lactate. Hinzpeter et al (2014) tested two different recovery protocols (passive and active) with 21 athletes with a mean age of 17 years. Immediately after a race paced swim, the passive group rested for 20 minutes and the active group carried out a steady state 20 minute swim recovery at 50-60% of their maximum velocity. The results showed that an active recovery was far more effective than passive. The active recovery reduced lactate levels by 68% whereas the passive recovery reduced lactate by 20%. While the studies above assessed whether an active or passive recovery was more effective, they fail to assess what type of active recovery would be the most effective, and no justification for choosing a velocity of 50-60% is provided. Active recovery has been found to be more effective throughout many studies (Greenwood et al. 2008; Tobekias et al. 2008; Weltman, 1977).

Similarly, a study by Casuso (2014) found that an in water recovery was more effective for repeat sprint ability in athletes. The study was carried out with 12 swim athletes with a mean age of 15 years. The study followed a cross over design which involved athletes carrying out 5 x 100m all out swims with either five minutes in or out of water recovery between. Although no significant difference was found In water recovery had a lower decrease in performance. A study by EY (1997) also found that after an active recovery lactate levels were lower and there was less of an impact on repeat sprint ability when compared with passive recovery.

Water and land based recoveries:

There have been studies carried out to investigate whether active recovery should be performed on land or in water. In swimming, sometimes there is no swim down pools available for athletes to carry out their cool down which leaves athletes with no choice but to use a land based cool down. Lomax (2012) investigated the effectiveness of three recovery protocols on the removal of lactate in swimmers after a race paced swim. The study was carried out with 33, well trained, youth swimmers (18 male and 15 female). The race paced swim was carried out over 200m and the athletes carried out the swim in a stroke of their choice, as it would be applicable to competition situation. The study examined a land-based recovery, self-prescribed water-based recovery and a coach-prescribed water-based recovery. The land based recovery included 5 minute light walk, 3 minute skip (30 seconds on, 30 seconds off), 10 minute stretch and 2 minute rest. The self-prescribed requires athletes to swim steady state for 20 minutes. There was no instruction on how hard the athlete should swim, except for being told to swim at a steady state. The coach prescribed included a series of different strokes and varying intensities. There is a difference between the three types of recovery protocols, with the coach prescribing a larger work load. The self-prescribed and land based recovery have a lighter workload, with the self-prescribed being open to the athletes interpretation. The results demonstrated that lactate was higher after the land-based recovery protocol than the two water-based recoveries. Lactate was lowest when measured after the coach prescribed recovery (1.8 ± 0.9 mmol/L), which had varying intensities and strokes. It was closely followed by the self-prescribed recovery (2 ± 1.2 mmol/L) which involved athletes swimming steady state for 20 minutes. This study suggests that a water-based recovery with varying intensities is more effective in the removal of lactate, which will increase athletes repeat swim ability. This study did not follow a cross over design. Athletes were tested across a single testing day, with different athletes carrying out the different recovery protocols. This is a limitation to this study as people may recover differently, which could have allowed for differences in the results. A cross over study design would have worked better as each of the athletes would have carried out both of the testing protocols, giving comparable results.

Electrical stimulation has also been used as a recovery protocol in swimming. In a study carried out by Neric et al (2009), the effectiveness of three different recovery protocols in removing lactate in swimmers after a race paced swim was investigated. The study was carried out with 30 swimmers (19 male and 11 female), and the race paced swim was 200 yards with all athletes swimming front stroke. The study investigated the efficiency of an active submaximal swim, passive resting and a transcutaneous electrical muscle stimulation recovery protocols on the removal of lactate. The transcutaneous muscle stimulation involved low-frequency submaximal muscle contractions in the athletes thighs and back, for 20 minutes. The theory behind using this was to increase blood flow to aid the clearance of lactate (Neric et al, 2009). The passive resting involved athletes sitting in a chair on the pool deck for 20 minutes. The submaximal swim, which proved most effective, involved athletes swimming steady state at 65% of their 200 yard swim time for 20 minutes. The evidence is in favour of the concept that a submaximal swim is effective as a recovery protocol but the study is only looking at one in water recovery protocol. Transcutaneous muscle stimulation and passive resting are both out of water recovery protocols, therefore still comparing active water based and land based recoveries. Transcutaneous muscle stimulation was effective in reducing lactate levels in athletes but blood lactate levels were significantly lower in the swimming recovery. A practical limitation to this study is that muscle stimulation equipment is very expensive, and it would not work well for large swim clubs, with multiple athletes trying to recover at once. The equipment would be in high demand and would not be freely available to the athletes.

Summary and Rationale:

In previous literature, there has been a large focus on whether active or passive recovery is optimal to return swimmers to baseline physiological levels (Mota et al, 2017; Hinzpeter et al, 2014). The literature sways heavily in favour that active recovery is far more effective than passive recovery and also suggests that land based recoveries are not as effective as water based recoveries in the removal of lactate (Lomax, 2012). It is evident that an active recovery protocol is optimal for athletes in removing lactate after a race paced swim. Water based recoveries have been proven to be more effective in the removal of lactate and returning athletes to baseline physiological levels after a race paced swim (Lomax, 2012). It has also been found that swimming a submaximal, steady state swim of 65% is an effective velocity for athletes to swim at in order to maximize lactate removal (Neric et al, 2009). The studies use heart rate and rate of perceived exertion to measure the effectiveness of the recovery protocols and to monitor the increasing intensity in lactate (Lomax, 2012). The previous studies compare active and passive recoveries, and water and land based recoveries, but they do not compare active, water based recoveries. Currently in practice, a high velocity overload protocol appears to be used as an optimal recovery strategy among swimmers during competitions. Limited evidence exists investigating whether a high velocity overload swim could be better than a steady state swim which has previously been shown as effective for improving recovery (Lomax 2012, Neric et al 2009). Therefore, the aim of this study was to investigate whether a low intensity swim or a low intensity swim with high intensity bursts (high velocity overload) was more effective in allowing swimmers to optimally recover and return to baseline physiological levels following a simulated swim race.

Research questions:

- What are the effects of steady state recovery on lactate, heart rate and rate of perceived exertion?
- What are the effects of high velocity over load recovery on lactate, heart rate and rate of perceived exertion?
- When comparing recovery strategies (steady state and high velocity overload), which method is more effective as a recovery strategy for swimmers?

Methods:

Conceptual framework:

This randomized control trail was carried out over one day with 12 athletes, who were all members of the National Aquatic Center (NAC) swim team. An overview of the study design is presented in figure 1.

The testing day consisted of three testing stages:

1) Pretest stage: In this stage all the athletes carried out the same warm up. The warm up consisted of 100m for 1:50 minutes 8 times and 150m for 2:45 minutes 4 times. The warm up took 22 minutes. After the warm up the athletes' lactate, heart rate (HR) and rate of perceived exertion (RPE) were taken for baseline levels.

2) Exercise stage: The athletes then carried out a race paced swim of 200m. The athletes HR and RPE was taken immediately and lactate was taken 2 minutes after the swim, to ensure blood values were at their peak (Goodwin, Harris, Hernández, & Gladden 2007).

3) Post-test stage: Athletes were randomly assigned a recovery protocol A or B. A high velocity over load recovery (swimming for 15m at 100% Velocity and then swimming at 50% velocity for the rest of the length) was used with one half of the group for 8 minutes, this was named group A, while group B under went a steady state low intensity recovery, at 65% of maximum velocity for 8 minutes. Velocity was estimated by using the athletes past competition time for 200m.

At the testing session, the participants returned all informed consent forms. The participants characteristics were gathered and assessed including age, height and body mass.

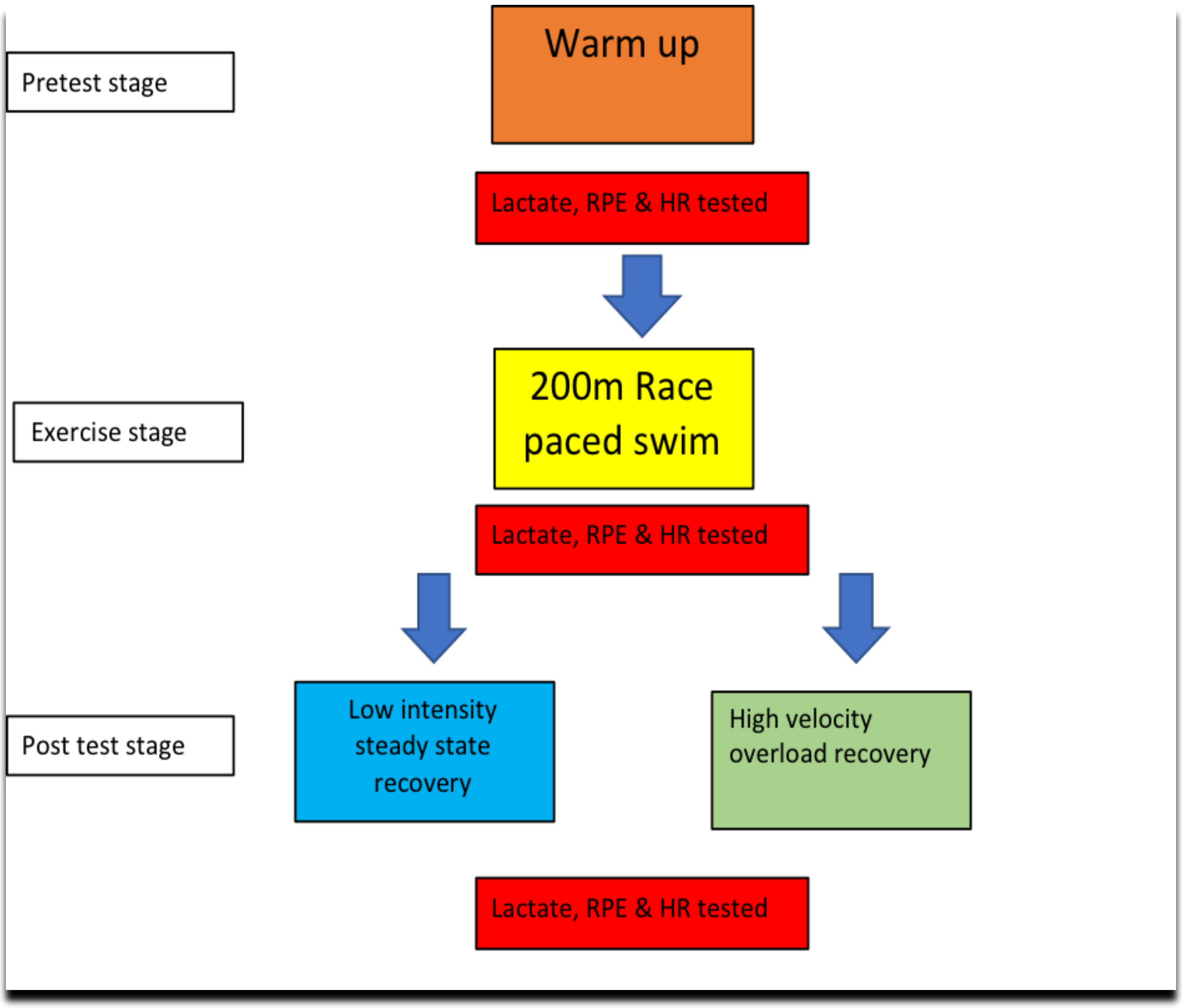


Figure 1: Conceptual Framework

Population:
The research study was carried out with 12 senior level swimming athletes who compete at a national and international level. The participants were both male (n=4) and female (n=8), aged between 14 and 18 years old. The athletes are all members of the NAC swim team and participants volunteered to be part of the testing.

Variables/concepts:
Athletes HR, RPE and lactate were tested after the warm up, after the race paced swim and then after the recovery protocol. The variables measured included:

- Lactate - Athletes lactate was taken from the ear lobe using a lactate pro monitor, before they underwent exercise and after each stage. Ahlgrim, Prettin , Röcker (2017) found that average resting lactate would be expected to be 1.26 ± 0.358

mmol/l. According to Lucertini et al (2017), blood lactate is the most widely used method of monitoring muscular fatigue in athletes.

- Heart rate - Athletes heart rate was taken by the athlete manually by checking their pulse after each exercise stage. The athlete counted the number of beats in the 15 seconds after they had carried out an exercise stage and that number was multiplied by four. HR has been shown to increase with exercise intensity (Yamamoto, Hughson, & Peterson,1991), while resting heart rate in well trained swim athletes would be expected to be under 70 bpm at rest (Maglischo, 2003).

- Rate of perceived exertion (RPE) – the 1-10 RPE scale (Appendix 1) was used with athletes as this was the scale they were efficient in using, which allows the athlete to indicate how hard they perceived the workload to be (Borg, 1982). The athletes were asked their RPE after the warm up, exercise stage and after the recovery protocol.

Warm up -

- Athletes carried out the same warm up.
- The warm up consisted of 8 x 100m in 1:50 and 4 x 150m in 2:45.
- After the warm up lactate, HR and RPE was tested.

Exercise stage -

- Athletes carried out a 200m race paced swim in a stroke of their choice.
- Athletes RPE, lactate and HR was tested.

Recovery stage –

- Athletes were randomly assigned a recovery protocol.
- One group carried out a steady state recovery and the other group carried out a high velocity overload recovery.
- After the recovery protocol athletes HR, RPE and lactate was tested.

Ethical considerations:

Participants were assigned an individual identification number and were never associated by their name, which protected their identity throughout the study. All data collected was placed in a password protected file. No participant was in receipt of payment for partaking in the study. Participants were required to complete and sign an informed consent form (see appendix 2) and they were aware that they could remove themselves from the study at any time. Although athletes were pushed to race pace, it was no different than their normal racing days. Lactate testing was carried out using precautions and athletes were able to withdraw at any stage if they were not comfortable. Disposable lactate strips were used for each athlete and all was properly disposed of. The tester had received the Hepatitis B Vaccine and Gloves were worn at all times.

Results:

Participant characteristics

Twelve swimmers completed the testing (males n=4 females n=8). Group A (high velocity overload recovery) consisted of 2 males and 4 females whilst Group B (steady state recovery) had 2 males and 4 females. Table 1 presents the participants characteristics Participants ranged in age from 14 to 18 years and there was no significant difference in age (p=0.68), height (p=0.71) or weight (p=0.35) noted between the groups.

Table 1: Participant Characteristics

	Group A N = 6	Group B N = 6
Age (yrs)	15.6 ± 1.5	16.3 ± 1.2
Height (cm)	177.0 ± 11.6	174.1 ± 8.1
Weight (kg)	67.8 ± 9.6	62.6 ± 7.7

Data presented as mean ± SD

Baseline characteristics:

Table 2 presents the baseline characteristics of all the swimmers .There was no significant differences between any of the variables within the groups. There was no difference in the lactate (p=0.82), Heart rate (HR) (p= 0.87) and RPE (t (10) = 0.51, p=0.61) between the two groups at baseline.

Table 2: Baseline characteristics

	Group A	Group B
Lactate (mmol/l):	1.8 ± 1.0	1.7 ± 1.0
Heart rate (bpm):	108.7 ± 7.3	108.0 ± 7.2
RPE:	2.2 ± 1.6	2.5 ± 1.0

Data presented as mean ± SD

Race paced swim:
All swimmers performed front crawl. Times for the race paced swim ranged from 133.3 ± 9.6 seconds. Between the two groups, there was no significant difference between any of the variables or in the swim time (p=0.26). Table 3 shows the lactate (p=0.25), HR (p=0.19) and RPE (p=1) results after the race paced swim for groups A and B. There was no difference between the two groups before the recovery protocol was carried out. In group B the lactate was 11.21 ± 3.8 mmol/l (range 4.6 to 14.1 mmol/l), however, there was no significant difference when compared to group A which was 8.73 ± 3.2 mmol/l (range 7 to 13.6 mmol/l).

Table 3: Race pace swim characteristics

	Group A	Group B
Swim time (seconds):	130.0 ± 6.4	136.1 ± 12.7
Lactate (Mmol/l):	8.7 ± 3.8	11.2 ± 3.2
Heart Rate (bpm):	149.0 ± 8.2	156.0 ± 9.1
RPE:	9.3 ± 0.5	9.3 ± 0.5

Data presented as mean ± SD

After recovery characteristics:
Table 4 shows the characteristics of the athletes after they had carried out one of the recovery protocols (group A = high velocity overload recovery, group B = Steady state recovery). There was no significant difference between the groups for lactate (p=0.22),

HR (p=0.88) and RPE (p=0.59) when the variables were assessed after the recovery protocols.

Table 4: Characteristics after swimming recovery protocol

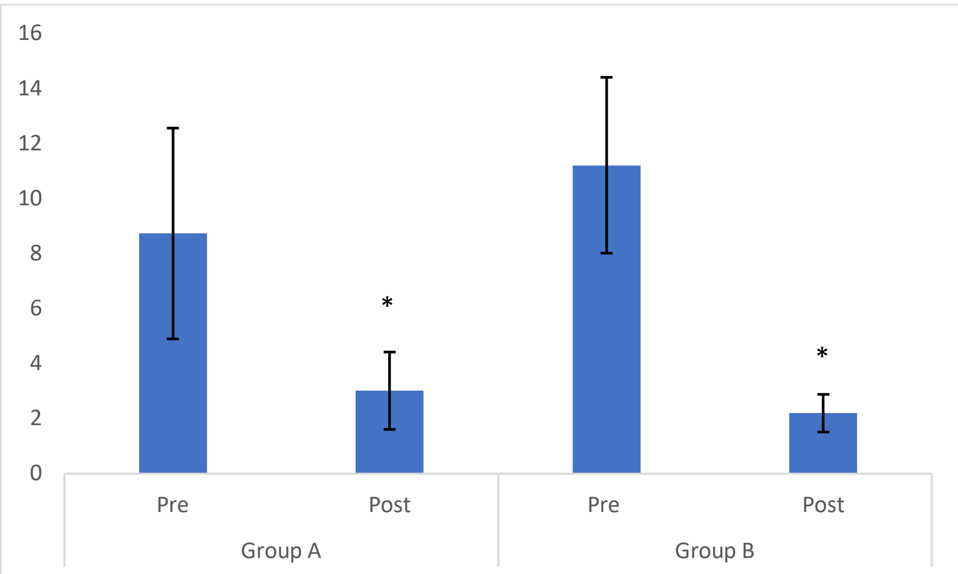
	Group A	Group B
Lactate:	3.0 ± 1.4	2.2 ± 0.7
HR:	117.3 ± 18.2	116.0 ± 12.9
RPE:	4.3 ± 0.8	4 .0 ± 1.3

Data presented as mean ± SD

Effectiveness of recovery protocols:

Change in lactate:

Figure 2 shows the pre (after the race paced swim) and post (after the recovery protocol) data sets of both groups. There was a significant difference in the lactates of both group A (P=0.002) and group B (p=0.002) from pre to post testing. The mean ± SD for group A pre recovery was 8.7 ± 3.8 mmol/l and for post was 3.0 ± 1.4 mmol/l. For group B the pre recovery tests mean ± SD was 11.2 ± 3.2 mmol/l and the post recovery test was 2.2 ± 0.7 mmol/l.



*p<0.05

Figure 2: Change in lactate within groups following recovery

The percentage difference in group A from pre to post was 66 ± 6 % and in group B there was 77 ± 9 % (mean ± SD) percentage difference in lactates from Pre to Post (ref figure 3). There was still no significant difference (P=0.12) between the percentage difference of the two groups.

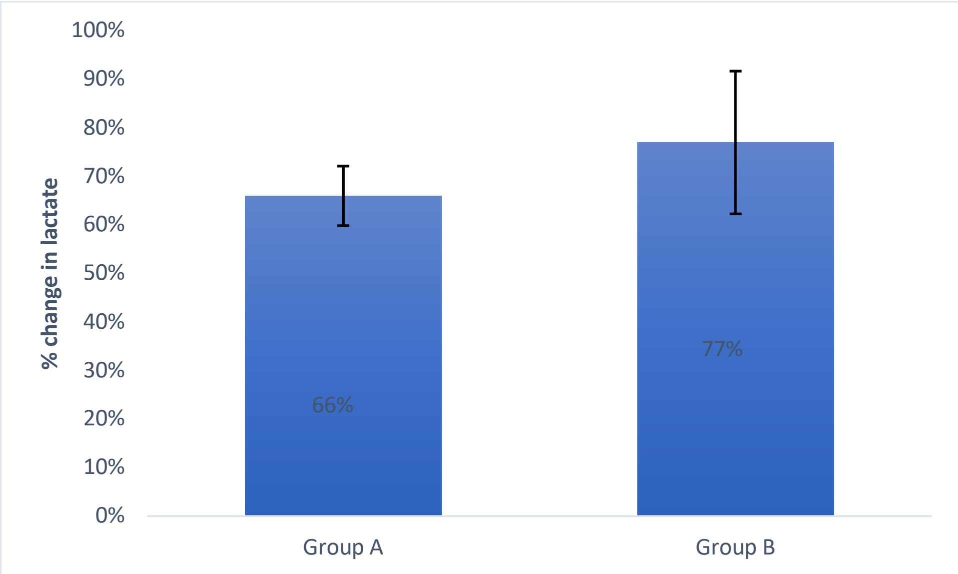


Figure 3: Percentage change in lactate following recovery

Figure 4 shows the individual changes in lactate of the groups. It is recommended with small sample sizes to use line graphs to show the change in data (Weissgerber, 2015). All athlete's lactates were reduced in the recovery protocols. The lactates from Group A pre (after the race paced swim) ranged 4.4 to 14.1 mmol/l and post (after the recovery protocol) ranged 1.5 to 4.3 mmol/l. Group B pre ranged 7 to 13.6 mmol/l and post ranged 1.3 to 3.1 mmol/l.

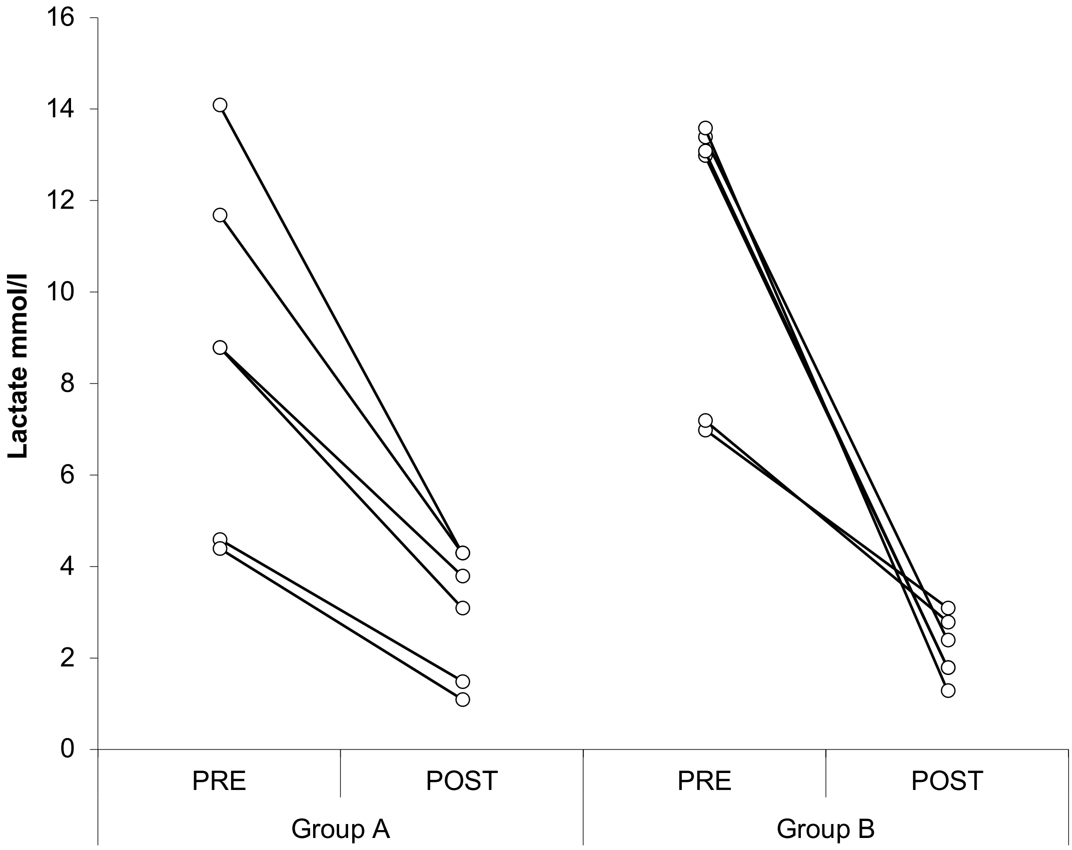
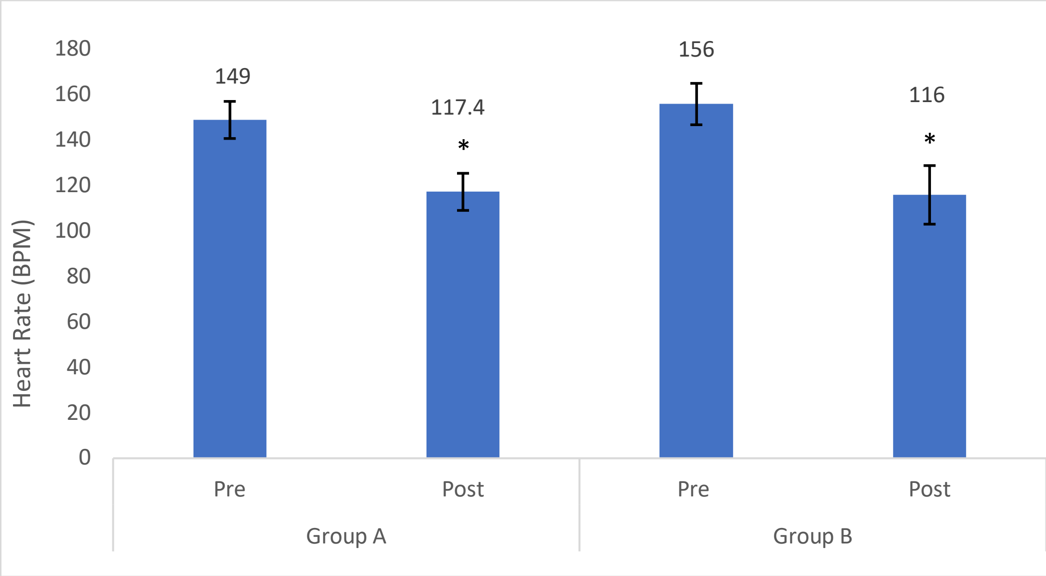


Figure 4: Individual changes in lactate from race paced to recovery

Change in Heart rate:

The changes in the athletes HR from pre to post recovery are shown in figure 5. There was a significant difference in group A (p=0.003) and group B (p=0.0001) from pre to post. The HR for group A pre recovery ranged from 142 to 164 bpm and post ranged from 88 to 136 bpm. The HR for Group B pre recovery ranged from 148 to 172 bmp and post ranged from 100 to 132 bpm. Figure 6 show the percentage change in heart rate. There was no significant difference between the percentage change in the heart rate from group A to B (p= 0.126).



*p <0.05

Figure 5: Changes in Heart rate following recovery protocol

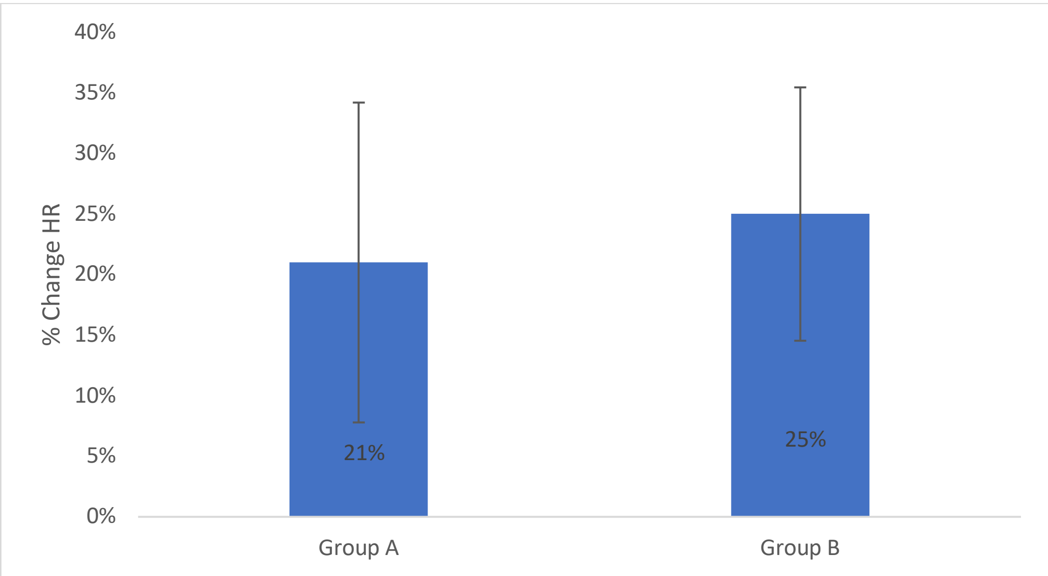
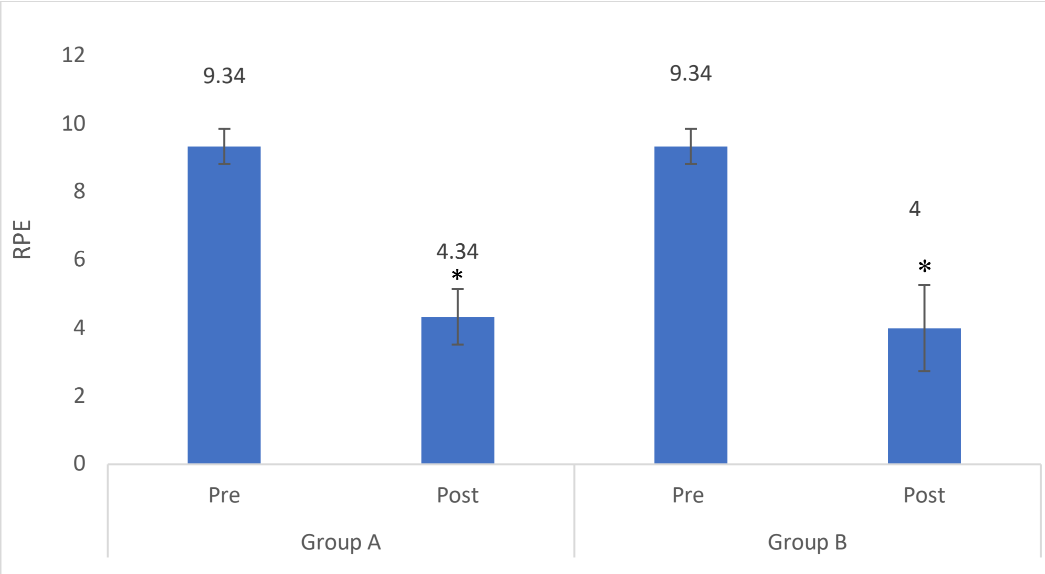


Figure 6: Percentage change in heart rate following recovery

Changes in RPE:
The changes in the athletes RPE from pre to post are shown in figure 7, which illustrates a significant difference in group A (p= 0.0004) and group B (p= 0.0003) from pre to post. Figure 8 shows the percentage change in RPE, noting no significant difference in RPE between groups A and B (p=0.56).



*p>0.05

Figure 7: Changes in RPE following the recovery protocol

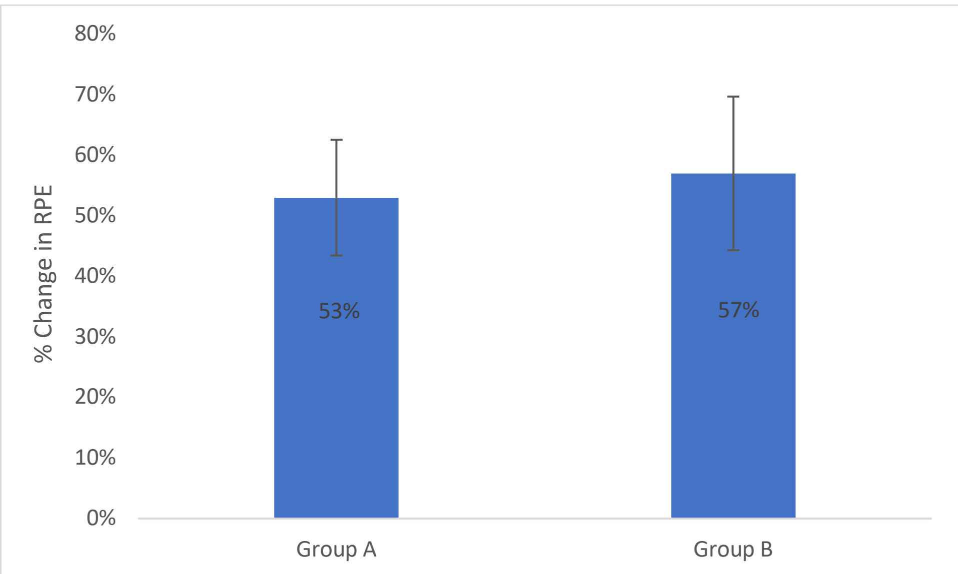


Figure 8: Percentage change in RPE

Discussion:

The aim of this study was to compare the effectiveness of two different recovery protocols on returning athletes to baseline physiological levels following a 200m race paced swim. The recovery protocols were a high velocity overload protocol, which the athletes on the NAC swim team are currently undertaking during training and competitions and the second recovery was a steady state recovery protocol. The results demonstrated that both of the recovery protocols were effective in removing lactate from the athletes after a race paced swim. After the race paced swim the recovery protocol was performed, and it significantly reduced the athlete's lactate, heart rate and RPE. The high velocity overload recovery, which had been working effectively for the NAC swim team, proved to be effective during the study. It reduced the athletes lactate, HR and RPE. The steady state recovery protocol was also effective in reducing the athletes lactate, HR and RPE. There was a significant reduction in all of the variables from after the race paced swim to after the recovery protocol.

When tested at baseline, there was no difference between the lactate in the two groups. A study by EY (1997), suggests that the lower the lactate concentrations after a recovery protocol the better the swim times will be in subsequent races. Due to the nature of swimming competitions, the removal of lactate is very important in ensuring that athletes will be recovered and ready to race again. The results of the Ey (1997) study is in accordance with this study as after the recovery protocols the mean lactate of Group B (steady state) was lower than the lactate in group A (high velocity overload). Lactate levels being lower in group B would result in a more effective recovery. Both the high velocity overload and the steady state recovery protocol were effective in reducing blood lactate levels in athletes. There was a significant difference from the race paced swim to after the recovery protocol in the high velocity overload and the steady state groups which may suggest that both recovery protocols are effective and efficient to use.

There was a large percentage change in the lactate levels of the athletes from the race paced swim to after the recovery protocol. Blood lactate levels reduced by 66% after the athletes performed the high velocity overload recovery and it reduced by 77% after the steady state recovery. A paper by Elferink-Gemser et al (2011), discusses how small the window of opportunity is for elite athletes and how they must try and maximise all possible potential, by carrying out the basics well and improving wherever they can. In sport, athletes and coaches are always trying to get some sort of advantage, even if it is just 1% of a difference. The steady state swim recovery had an 11% difference to the high velocity overload recovery. Incorporating a recovery technique that may make a 11% difference could help maximise the athletes performance. If each time the athlete carried out their recovery protocol and it reduced their lactate by 11% more, it would make a huge difference to the athletes performance. The athlete would be recovering more effectively which may help their repeat sprint ability.

A study carried out by Greenwood et al (2008), reports that the optimal velocity to perform a cool down was at an average of 86% of an athletes maximum swim time. This present study is contradictory to Greenwoods et al (2008) findings as the steady state recovery, which was found to have decreased the athletes lactate more than the high velocity overload recovery, was carried out at 65% velocity. Previous literature also suggests that swimming at 65% velocity is optimal for reducing lactate (Mota et al. 2017; Neric et al, 2009). This present study supports the findings of Mota et al (2017) and Neric et al (2009) in that active recovery at a self-prescribed rate of 65% is more effective.

There was no significant difference between the heart rates and rate of perceived exertion at baseline, after the raced paced swim or after either of the recovery protocols. These markers were used to show that there was no difference between the two groups. The results of these variables were important as they ensured that one group was not being trained harder than the other. The heart rate and RPE would have reflected a difference after the race paced swim if one group were being pushed more. The recovery protocols did not have a different effect on the HR or RPE of the athletes.

Limitations:

There are a number of limitations to this present study, with the main limitation being that the study did not follow a crossover design. Initially, the study was planned to follow a cross-over design but due to reasons outside the control of the researcher it was not possible, as the athletes were performing at an elite level, and were not easily accessible. A cross over design would have worked more effectively as it would show that athletes did not recover differently, and it would have compared the athlete’s individual responses to each recovery protocol. Another limitation to the study would be the small sample size that was used. It may have been possible to find a bigger difference between the recovery protocols with more athletes. Wearable heart rate monitors would also have been far more accurate than athletes taking the heart rate themselves. Lastly, the groups consisted of both males and females, which may have affected the results of the data, as gender may influence how an athlete recovers.

Conclusion and practical applications:

The findings from this study show that both the high velocity overload recovery and the steady state recovery are effective in removing lactate in athletes following a race paced swim. Both the recovery protocols are effective in returning the heart rate and rate of perceived exertion back to baseline levels. The high velocity overload recovery replicates the recovery protocol currently being undertaken by a number of swim teams. The study shows that just because a number of teams are carrying out a recovery protocol, it does not always mean that it is the most effective. There was no significant difference between the two groups, but the evidence sways in favor of the steady state recovery being slightly more effective because of the 77% change in the group after the recovery when compared with the 66% change after the high velocity overload recovery.

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Appendices:

Appendix 1: RPE scale

rating	description
0	NOTHING AT ALL
0.5	VERY, VERY LIGHT
1	VERY LIGHT
2	FAIRLY LIGHT
3	MODERATE
4	SOMEWHAT HARD
5	HARD
6	
7	VERY HARD
8	
9	
10	VERY VERY HARD (MAXIMAL)

Appendix 2: Informed consent form

INFORMED CONSENT FORM

My name is Jane Crowley, and I am a final year undergraduate student studying Sports Coaching and Performance at Waterford Institute of Technology. I am inviting you to participate in a research study I am completing as part of my final year work. Involvement in the study is voluntary.
The aim of the research study is to see the effectiveness of different swimming recoveries. In practice, we use different recoveries methods and we want to see how effective they are. This study will consist of a testing day which will occur during a training session assessing two different recovery methods: Steady state low intensity recovery and a high velocity overload recovery.

Each testing day will consist of three testing stages:

1) Pretest stage: all athletes will carry out the same warm up. After the warm up the athletes' lactate, heart rate (HR) and Rate of perceived exertion (RPE) will be taken for baseline levels.

2) Athletes will carry out a race paced swim of 200m. The athletes HR and RPE will be taken immediately after but lactate will be taken 2 minutes after the swim.

3) Athletes will be randomly assigned a recovery protocol. A steady state low intensity recovery, at 60% of maximum velocity will be carried out by one group. Velocity will be estimated by using athletes past competition results time. A high velocity over load recovery (swimming for 15m at 80% Velocity and then swimming at 50% velocity for the rest of the length) will be used with the other half of the group. On a separate day, participants will repeat the testing session incorporating the alternative recovery protocol.

Lactate will be assessed by a pin prick to the fingertip and taking a small blood sample. Heart rate will be tested using heart rate monitors and RPE will be tested using a scale from 6 – 20 to assess how they are feeling.

At the first testing session, all participants age, height and body mass will be gathered too.

All information will be kept confidential. All data will be anonymized, I will assign a number to your collected data and no individual data will ever be presented. Information will only ever be presented as group averages in articles I write or presentations I make. No individual participant will ever be named. The data will be kept in a password protected file which only my thesis supervisor and I will have access to. The data will only be held until September 2019, when the thesis will be fully complete.

The benefit of this research is that you will be helping to understand which swimming recovery method works best for athletes after a race paced swim which is so important when swimmers have so many competitions at an individual meet. If you do not wish to continue, you have the right to withdraw from the study, without penalty, at any time.

Please feel free to ask any questions that you may have about the research; I will be happy to explain anything in greater detail. I can be contacted my email at janecrowley96@gmail.com

I have read and I understand the provided information and have had the opportunity to ask questions. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving a reason and without cost. I voluntarily agree to take part in this study.

Print name of parent/guardian:

Signature of parent/guardian: Date

Print name of participant

Signature of participant Date

Appendix 3: Testing sheet used on testing day

Gender: ________________

Age: ________________

Height: ________________

Weight: ________________

	Test 1	Test 2	Test 3
Heart Rate			
Lactate			
RPE			