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Comments	Section
	Title and Abstract (5%) Title to include: A concise indication of the research question/problem. Abstract to include: A concise summary of the empirical study undertaken.
	Introduction and literature review (25%) To include: outline of context (theoretical/conceptual/applied) for the question; analysis of findings of previous related research including gaps in the literature and relevant contributions; logical flow to, and clear presentation of the research problem/ question; an indication of any research expectations, (i.e., hypotheses if applicable).
	Methods and Research Design (15%) To include: details of the research design and justification for the methods applied; participant details; comprehensive replicable protocol.
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A comparison of the effects of effleurage and passive rest on blood lactate removal in track athletes after exercise.

(Dissertation submitted under the SCRAM area)

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A COMPARISON OF THE EFFECTS OF EFFLEURAGE AND PASSIVE REST ON BLOOD LACTATE REMOVAL IN TRACK ATHLETES AFTER EXERCISE.

Cardiff Metropolitan University

Prifysgol Fetropolitan Caerdydd

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Abstract

The purpose of this study was to discover if sports massage had a greater effect on the removal of blood lactate after high intensity exercise when compared with passive rest. Nine university level track athletes (19.9 ± 1.8 years, 175.3 ± 7.1 cm, 63.4 ± 6.7 kg) performed two 400m runs over a period of two weeks. Recovery interventions were administered after the 400m run and consisted of sports massage, using the effleurage technique, and passive rest. A randomised crossover design was utilised and each participant underwent both recovery interventions. Blood lactate was measured at four time points across the study, after the warm up, two minutes after the 400m, immediately after the 20 minute massage or passive rest and again 20 minutes after the initial recovery. Blood lactate was measured by taking whole blood from the fingertip and analysed using the Biosen analyser in milimoles per litre (mmol/L). Data was presented as mean ± standard deviation (SD) and significance was accepted at $p < 0.05$ level. A paired t-test revealed no significant difference ($p > 0.05$) between the blood lactate values after the warm up and after the 400m between week one and week two, and a significant difference ($p < 0.001$) between post warm up and post 400m blood lactate values. A two way repeated measures ANOVA revealed no significant difference ($p > 0.05$) between the sports massage and passive rest interventions. Sports massage did not improve the removal of blood lactate when compared to passive rest, indicating that massage did not have a significant effect on the blood lactate clearance after exercise.

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

During an athlete's competitive season, recovery needs to be strategically planned as part of the training programme to achieve the desired peak performances (Greener *et al.,* 2013). As track and field athletes are often required to compete more than once within a day in heats, semi finals and finals for sprinters, it is important to consider the best strategies to optimise recovery between events as well as gaining a balance between training, competing and recovery (Reilly and Ekblom, 2005; Brummit, 2008; Bird, 2013). Recovery methods such as rehydration, active cool-downs and self-massage have been established as adequate forms of recovery from intense exercise, with sports massage suggested to enhance recovery from any muscle damage and fatigue (Faigenbaum, 2004; Best *et al*., 2008).

Events ranging from 100 up to 800 metres (m) are often classed as high intensity exercise due to the high contribution of anaerobic energy metabolism during a large portion of the event, although aerobic energy metabolism begins to contribute to a larger extent after 30 seconds (Spencer and Gastin, 2001). The anaerobic glycolytic system is predominantly utilised during high intensity exercise to replenish the increasing amount of adenosine triphosphate (ATP) required to answer the energy demands (MacDougall *et al.,* 1999). Due to the heavy reliance on this metabolic pathway during high intensity activity such as the 400 and 800m, levels of blood lactate consequently increase, which in turn leads to fatigue and decreased levels of performance (Caruso *et al.,* 2011; Cairns, 2006; Enoksen *et al.,* 2011; Hanon *et al.,* 2012). The ability to clear the lactate from the body is therefore vital after exercise, with oxidative cells and increased blood flow being the most important factors in the subsequent utilization and elimination of lactate (Gladden, 2004; Hashimoto, 2011). The heart can be seen as one of the most important muscles for the uptake and utilisation of lactate, and increased blood flow leads to the oxidisation of the metabolite into carbon dioxide (Stanley, 1991).

It is believed that a slower rate of lactate clearance after high intensity anaerobic exercise can lead to a slower recovery from fatigue (Hemmings *et al.,* 2000), indicating that sports massage can be a vital element of athletic recovery to increase blood flow and consequently, the uptake and utilisation of lactate. Specific techniques in sports massage can enhance the blood flow of localised muscles, which in turn can lead to a greater rate of lactate clearance after high intensity exercise (Martin *et al.,* 1998). Sports massage is defined as the manipulation of soft tissue to promote an athletes health, well being and performance, and has increased in popularity within the competitive environment (Benjamin and Lamp, 1996; Brummit, 2008). Using techniques such as effleurage can increase cell permeability whilst also improving venous and lymphatic flow, which in turn increases the supply of nutrients and removal of waste products (SPS Ltd, 2003).

1.2 RATIONALE

Maintenance of performance is an important factor when track athletes have more than one race during a single competition or event (Monedero and Donne, 2000). Studies have previously looked at the effect of massage on blood lactate removal after strenuous bouts of exercise (Martin *et al.,* 1998; Monedero and Donne, 2000; Hemmings *et al.,* 2000; Wiltshire *et al.,* 2010; Cé *et al.,* 2013), but have failed to find a significant difference between sports massage and other recovery interventions. Although these studies discovered no significant difference in the removal of blood lactate, massage techniques such as vibrations, petrissage, tapotement and stretching were used, which are not seen to have favourable effects on blood flow and removal of waste products (SPS Ltd, 2003). These studies therefore do not sufficiently assess the effect of massage on blood lactate removal due to the use of inadequate sports massage techniques.

As these studies have used massage techniques that were not effective in the removal of waste products and enhancement of venous flow, this study aimed to determine the effects of effleurage, which directly impacts venous and lymphatic flow (Holey and Cook, 2011), when compared with passive rest on the removal of blood lactate after strenuous exercise.

1.3 AIMS AND HYPOTHESIS

The aim of this study was to compare the sports massage technique of effleurage with passive rest to determine if it had a more beneficial effect on the removal of blood lactate after strenuous exercise. It was hypothesised that the sports massage recovery protocol with the use of effleurage would have a larger influence on the removal of blood lactate.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 HIGH INTENSITY TRAINING

High intensity training can be defined as repeated bouts of exercise completed at an intensity higher than the anaerobic threshold, for approximately 10 seconds to 5 minutes (Sjokvist *et al.,* 2011). The anaerobic threshold is defined as the intensity of exercise where the uptake of oxygen is not enough to answer the energy demands, and is often associated with the highest intensity at which lactate is equally produced and dispersed (Svedahl and MacIntosh, 2003; Erkmen *et al.,* 2012). High intensity training should be commenced at approximately 90 - 95% of VO_2 max and above the lactate threshold, which produces a significant increase in blood lactate levels (Svedahl and MacIntosh, 2003; Schoenfeld and Dawes, 2009; Sjokvist *et al.,* 2011).

Many sports such as rugby and basketball demand athletes to be aerobically fit whilst having the ability to recover from short high intensity bouts of exercise (Hoffmann *et al.,* 2014). The study by Hoffman *et al.* (2014) highlighted that as field sports require various demands on power, strength and recovery abilities, high intensity training is preferred to long duration and low intensity sessions. High intensity training is not only utilised in field sports, and a study published by Spencer and Gastin (2001) discovered that the 200m had a 71% anaerobic contribution and the 400m had a 57% anaerobic contribution, whilst the 800 metre event had a higher aerobic contribution (66%:34%). This suggests that training for 200 and 400m events needs to contain a high percentage of high intensity anaerobic exercise to replicate the demands of the performance, whilst also developing an increased tolerance to blood lactate and the lactate threshold.

2.1.1 The Anaerobic Glycolytic Metabolic Pathway

The production of energy when participating in high intensity training causes rapid depletion of ATP, requiring other metabolic pathways to be activated (Westerblad *et al.,* 2010). The structure of an ATP molecule is shown in Figure 2.1, consisting of one adenosine and three inorganic phosphate (P_i) groups (Wilmore and Costill, 2004).

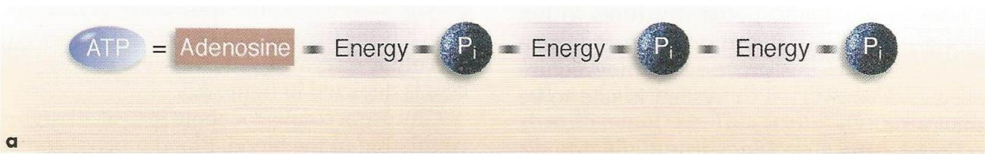

Figure 2.1 One molecule of ATP (Wilmore and Costill, 2004, p. 123)

Anaerobic glycolysis is the metabolic pathway responsible for reproduction of ATP molecules when both ATP and phosphocreatine (PCr) stores decrease, and often leads to an accumulation of lactate in the muscles (Gorostiaga *et al.,* 2010). Glycogen is vital for the production of ATP through anaerobic glycolysis, with the enzyme phosphorylase being responsible for its breakdown into glucose residues, which then enter the glycolytic pathway to essentially be converted to pyruvate (Westerblad *et al.,* 2010). This metabolic pathway, shown in Figure 2.2, does not require oxygen, but the fate of the pyruvate produced is determined by oxygen obtainability. Therefore, due to anaerobic glycolysis not utilising oxygen for energy metabolism, lactic acid is produced (Wilmore and Costill, 2004).

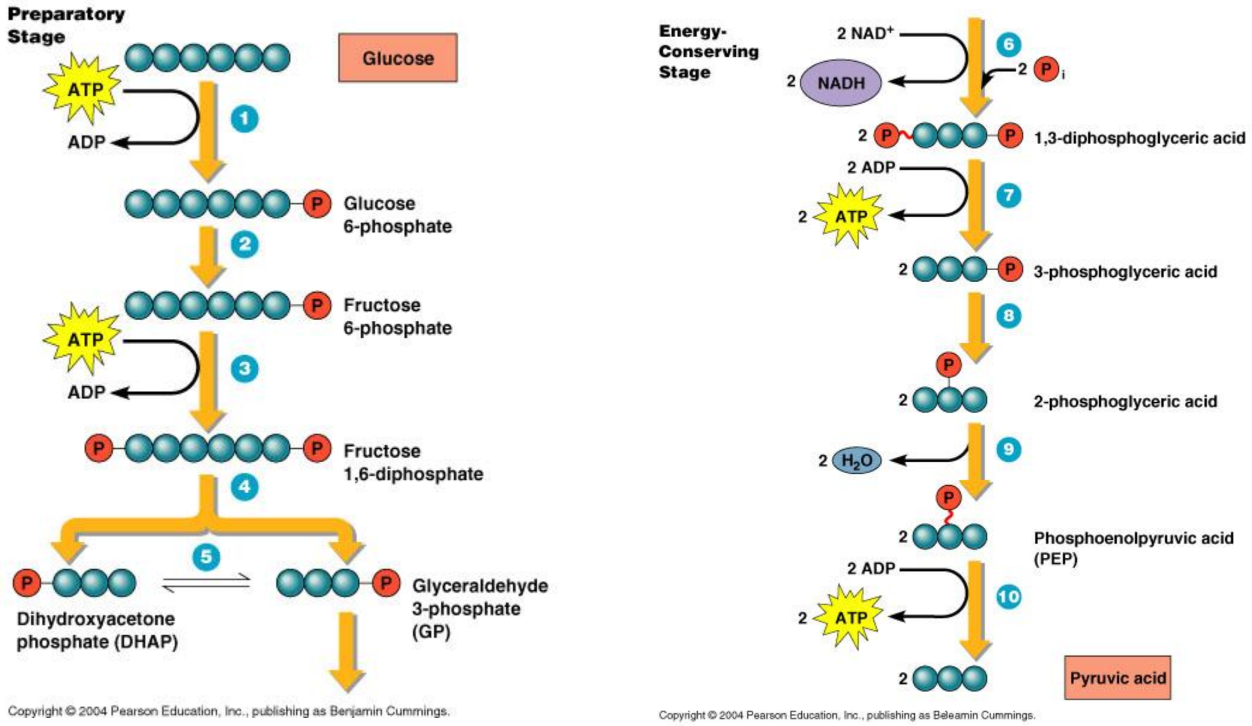

Figure 2.2 The anaerobic glycolytic metabolic pathway (Pearson Education, 2004)

2.1.2 The Production of Blood Lactate

During brief high intensity exercise, the release of calcium ions from the sarcoplasmic reticulum in the muscle is primarily responsible for controlling glycogen metabolism, and therefore anaerobic glycolysis (Chamari *et al.,* 2001). Although lactate is initially produced in the muscles, blood plays a vital role in the transportation of lactate to areas in the body where it can be eliminated (Hildebrand *et al.,* 2000). Different authors have explored the time concepts related to the initial stimulation of anaerobic metabolism and consequent lactate production during exercise (Chamari *et al.,* 2001; Beneke *et al.,* 2002; Franchini *et al.,* 2011). Exercise that requires the use of anaerobic glycolysis usually lasts between 10 and 100 seconds and includes events such as 100 and 400m sprints (Raeburn and Dascombe, 2009).

In a study published by Chamari *et al.* (2001), the concept that the anaerobic metabolic pathway is stimulated within the very first few seconds of exercise was explored. The blood lactate concentrations in volleyball players after maximal vertical jumps were analysed, discovering that lactate levels increased significantly after experimental protocols. This study concluded that the anaerobic metabolic pathway was initiated within a second of high intensity exercise, suggesting that anaerobic metabolism was immediately used to restore ATP stores.

Contradictory to this, Beneke *et al.* (2002) suggested that both the alactic and lactic acid anaerobic energy systems were the main contributors to energy metabolism in a 30 second Wingate anaerobic test (WAnT); 31.1% alactic anaerobic and 50.3% lactic acid anaerobic. It was highlighted that alactic metabolism was the main contributor within the initial seconds of the WAnT, which then stimulated the enzyme phosphofruktokinase to increase the rate of anaerobic glycolysis (Beneke *et al.,* 2002). This study therefore disagrees with Chamari *et al.* (2001), suggesting that anaerobic metabolism does not contribute to energy metabolism until at least five seconds after initial commencement of exercise. Similarly to this study, Franchini *et al.* (2011) discovered that the alactic anaerobic energy system dominated over the lactic acid anaerobic system in a Special Judo Fitness Test, which consisted of bouts of exercise for 15 and 30 seconds with 10 seconds rest intervals. The alactic contribution throughout this test was significant ($p < 0.001$) suggesting that in short bouts of high intensity activity with intermittent rest periods, the lactic acid anaerobic energy system does not have a large influence on the restoration of depleted ATP stores.

The contradiction between the findings of Chamari *et al.* (2001), Beneke *et al.* (2002) and Franchini *et al.* (2011) when investigating the contribution of energy systems may be explained by the intensity of the exercise. As Chamari *et al.* (2001) utilised very high intensity exercise, ATP stores would be depleted at a higher rate. This requires the lactic acid anaerobic system to replenish the adequate amounts of ATP for continued high intensity exercise, suggesting that the metabolic pathway recruited is dependent on the exercise intensity.

2.2 BLOOD LACTATE AND PERFORMANCE

The onset of blood lactate accumulation (OBLA) is an important factor that is considered an adequate measure for performance and training statuses in middle distance athletes (Santos-Concejero *et al.,* 2013). The concept of OBLA has been highly associated with fatigue during performance, and can be defined as the work rate at which the blood lactate levels of an individual has reached 4 milimoles per litre (mmol/L) (Figueira *et al.,* 2008; Chmura and Nazar, 2010). Due to the acidity of the lactate produced from anaerobic glycolysis, the capacity of calcium to bind during muscular contraction is delayed, which consequently results in fatigue and a decrement in performance (Wilmore and Costill, 2004).

In a study conducted by Nakamura *et al.* (2009), a comparison of the post exercise blood lactate levels between a repeated sprint ability test and intermittent fitness test was explored in team sports players. Both exercise tests induced similar results on the blood lactate levels, with repeated sprints significantly affecting the autonomic system and the regulatory abilities of the body (Nakamura *et al.,* 2009). This highlights the detrimental effects increasing levels of blood lactate can have on repeated sprint performance, demonstrating the importance of developing higher lactate thresholds to withstand these effects during match play.

Similarly, Bishop *et al.* (2003) investigated the effects of increasing hydrogen ion accumulation on repeated sprint ability in elite female field hockey players. This study showed a significant decrement in power ($p < 0.05$) with an increase in hydrogen ions in the plasma, suggesting that this factor is important to consider when optimising recovery of power output to allow the athlete to perform repeated bouts of high intensity exercise (Bishop *et al.,* 2003). Although this study did not explore the consequence of lactate production on repeated sprint ability, hydrogen ions in anaerobic glycolysis combine with pyruvate to produce lactate (McArdle *et al.*, 2001). This therefore reinforces the discoveries by Nakamura *et al.* (2009), emphasising that when anaerobic glycolysis is the main metabolic pathway used in the muscle, increasing levels of lactate can cause a detrimental effect on performance.

As lactic acid can cause negative effects on high intensity exercise (Monedero and Donne, 2000), it is important to minimise these effects and maximise recovery for consequent performances.

2.3 RECOVERY METHODS

Many sports demand repeated high intensity exercise bouts within close proximity to each other, requiring a quick turnover of muscle recovery and maintenance of performance (Carrasco *et al.,* 2011). During high intensity physical activity many systems within the body such as energy systems, musculoskeletal, endocrine and nervous systems are placed under stress, requiring the athlete to develop multiple strategies to promote and enhance their recovery (Reilly and Ekblom, 2005; Bird, 2013). Previous studies have investigated the effect of recovery techniques, specifically active and passive rest, on the removal of blood lactate after exercise (Monderro and Donne, 2000; Greenwood *et al.,* 2008; Franchini *et al.,* 2009; Ferreira *et al.,* 2011; Lomax, 2012).

Greenwood *et al.* (2008) and Lomax (2012) both compared various intensities of active recovery with passive rest to discover an optimum intensity for improved lactate removal. Greenwood *et al.* (2008) compared three different swimming intensities with passive rest in 14 male swimmers. The intensities of the recovery were speed at lactate threshold (V_{LT}), 50% of the lactate threshold ($V_{LT.5}$) and 150% of the lactate threshold ($V_{LT1.5}$), and it was discovered that the V_{LT} recovery intervention had a significantly greater effect on the removal of blood lactate ($p < 0.0001$) compared with both other intensities (Greenwood *et al.,* 2008). Although this study discovered that recovery associated with lactate thresholds improved the removal of blood lactate, it would be required for the coaches to have the appropriate lactate testing equipment to discover the lactate profile of each individual athlete. This suggests that a more appropriate measurement for the intensity of the active recovery need to be implemented in situations where lactate profiling is not readily available.

In a similar study conducted by Lomax (2012), 33 swimmers participated in three different recovery interventions; passive recovery, self paced swim and a coached swim. This study discovered that both self paced and coach prescribed recoveries had similar effects on the removal of blood lactate, with self paced decreasing from 10.5 mMol (±2.2) to 2.0 mMol (±1.2) and coach prescribed decreasing from 10.8 mMol (±2.8) to 1.8 mMol (±0.9) (Lomax, 2012). As heart rate values were used to identify the intensity of the 20 minute recovery, this demonstrates a more attainable recovery intensity for training environments when compared with lactate profiling.

Contrary to these studies, Ferreira *et al.* (2011) discovered that active recovery at a higher percentage of the anaerobic threshold removed 70% of the blood lactate produced after maximal exercise. This study compared passive recovery on land and water with cycling in immersion of water, and discovered that the active recovery intervention was enough to remove up to 67% of the blood lactate when compared with passive recovery. The authors stated that the intensity of the recovery should be defined by the anaerobic threshold and no other parameters, with an intensity of 85% being the optimum to maximise lactate removal (Ferreira *et al.,* 2011). This study contradicts the investigations by Greenwood *et al.* (2008) and Lomax (2012) where active recovery interventions were completed at intensity lower than 80% of the anaerobic threshold. Although this study discovered that 67% of the blood lactate was removed in the 30 minutes active recovery, athletes with more than one event in the space of a few hours need to minimise the length of recovery whilst optimising the removal of blood lactate and muscular fatigue.

Franchini *et al.* (2009) explored a shorter recovery intervention, consisting of 15 minutes of passive and active recovery after three different high intensity exercises, and discovered significant differences in lactate levels in half the time used in the study by Ferreira *et al.* (2011). It was discovered that after both the Wingate anaerobic test and the Special Judo Fitness test, passive recovery lactate levels were 7.39 mMol (±2.23) and 7.48 mMol (±2.99) whereas active recovery lactate levels were 5.42 mMol (±2.53) and 4.1 mMol (±1.26). This study highlighted that 15 minutes of active recovery using the percentage of VO_2 max was ample time for the athlete to fully recover for the most effective removal of blood lactate, showing that even a shorter amount of time for recovery can elicit significant decreases in blood lactate levels. This study can be more applicable to competitive environments than the study published by Ferreira *et al.* (2011) due to the decreased time frame for the removal of blood lactate.

The above studies highlight the importance of designating a specific exercise intensity for active recovery when the removal of blood lactate needs to be enhanced within a small time frame. As the studies have contradicting information on active recovery intensity, further studies should investigate the comparison of different active recovery intensities, as well as other recovery interventions that minimise the recovery time whilst maximising the rate of lactate removal. Many different strategies such as nutritional intake, compression clothing and massage can be employed to combat the causes of fatigue and accelerate recovery between performances (Nédélec *et al.,* 2013).

2.4 SPORTS MASSAGE

As 400 and 800m runners often have two races within a few hours of each other during a competition, it is vitally important to augment recovery to increase performance. An example of the multiple competitive demands for a middle distance track athlete could be seen in the South of England Championships in 2015, where there was three 400m races within one day (The Power of 10, 2015). As strenuous exercise can cause muscle damage and fatigue, a variety of techniques can be used to enhance recovery by speeding up the healing of strained muscles and relieving muscle tension (Best *et al.,* 2008). Sports massage can be used to manipulate the soft tissue and is often used by physical therapists to enhance recovery from exercise (Field, 1998; Brummit, 2008). The effleurage technique in sports massage is frequently used to aid the exchange of tissue fluids whilst improving venous and lymphatic flow, enhancing the effect on the removal of products such as lactate through light or deep stroking techniques (Holey and Cook, 2011).

Massage is widely utilised in competitive environments by practitioners who aim to optimise recovery for athletes from competitive events, and allow for the maintenance of performance when completing more than one event in a day (Galloway and Watt, 2004). Post event massage should be utilised within six hours after a competition to elicit the most effective physical recovery, and should be between 15 and 20 minutes in duration (Benjamin and Lamp, 1996; Findley, 2010). This recovery method can aid with the restoration of flexibility, reduction of muscle soreness and removal of metabolites such as lactic acid (Findley, 2010). The sports massage technique of effleurage can be seen to have many beneficial physiological effects such as assisting venous and lymphatic flow and the removal of chemical irritants (Holey and Cook, 2011). Acknowledging this, recovery from high intensity exercise that can cause an accumulation of blood lactate should benefit from the use of effleurage due to the physiological effects that can ensue.

2.4.1 Sports Massage and Performance

Historically, sports massage has been explored with regards to the benefits on post exercise recovery from muscle damage induced by exercise, which is typically of an eccentric nature (Best *et al.,* 2008). Previous studies have examined the various effects of sports massage on factors such as delayed onset of muscle soreness (DOMS), swelling and strength (Hilbert *et al.*, 2003; Jonhagen *et al.,* 2004; Zainuddin *et al.,* 2005; Hart *et al.*, 2005; Pinar *et al.,* 2012; Andersen *et al.,* 2013).

Mean power output (mpo) and peak power (pp) measurements were taken in a study by Pinar *at al.* (2012) after recovery interventions between two Wingate anaerobic tests. This study examined the effects of Electrical Muscle Stimulation, sports massage and passive rest on these measurements and found no significant differences ($p > 0.05$) between the recovery interventions, therefore demonstrating that sports massage was not an efficient technique to enhance recovery and improve consequent performance (Pinar *et al.,* 2012). The non-significant difference in power outputs may be due to effleurage being the chosen massage technique, and although this technique is used to enhance circulation and increase the effectiveness of movement of bodily fluids (Benjamin and Lamp, 1996), it is not effective in the improvement of subsequent performance. Research has previously shown massage to be an effective method for recovery from multiple performances, however the most effective technique for repeated exercise is yet to be identified due to differing demands of athletes and individualised responses to sports massage.

Similar results to Pinar *et al.* (2012) were seen in a study explored by Jonhagen *et al.* (2004) where 16 participants performed 300 maximal eccentric contractions on each leg. It was again discovered that there was no significant difference ($p > 0.05$) between the results of the maximal strength testing between massaged and control legs. As strength had not improved, light effleurage and petrissage were not efficient in enhancing local recovery and maintaining strength performance. As only one leg was massaged as part of the recovery protocol, it could be argued that the leg that served as the control would also receive the beneficial effects of massage due to the human body being a closed system, allowing the physiological effects such as increased blood flow effect the control leg. As light effleurage and petrissage are not found to have beneficial effects on repeated strength performance, this suggests the reason as to why no significant difference was discovered, due to the closed system passing the effects of massage around the whole body.

Numerous studies (Hilbert *et al.,* 2003; Hart *et al.,* 2005; Andersen *et al.,* 2013) have also explored the effects of sports massage on DOMS after high intensity exercise, such as the study by Hilbert *et al.* (2003), where 18 participants underwent maximal eccentric contractions whilst measuring peak torque. Massage was then administered to half of the participants legs using effleurage, tapotement and petrissage whilst the other participants served as the control. Participants then returned six, 24 and 48 hours after the massage for measurements of soreness intensity, which was measured using the Differential

Descriptor Scale consisting of two sets of 12 descriptor items (Hilbert *et al.,* 2013). Results discovered that both control and massage group experienced higher intensities of soreness at all hours after the intervention, with the massage group experiencing a lesser intensity at 48 hours (Hilbert *et al.,* 2003). This highlighted that sports massage was enough to alleviate the effects of DOMS after eccentric exercise and decrease the soreness felt at the following 48 hour mark. Although this was the case, soreness does not take effect until 24 hours after exercise, with peaks in soreness occurring between 24 – 72 hours (Armstrong, 1984). This raises the question whether the time frames in this study correctly assessed the effect of sports massage on DOMS, and suggests that a more appropriate time frame such as 48 – 96 hours after exercise should be implemented in future studies.

Hart *et al.* (2005) discovered similar results when they compared sports massage and active rest on 19 participants after DOMS was induced through eccentric contractions of the triceps surae. Each participant then returned to the laboratory 24, 48 and 72 hours later to receive an active rest and sports massage protocol, which consisted of five minutes of cycling and 5 minutes of petrissage and effleurage. It was recognised that sports massage was not effective for the reduction of pain and swelling when compared with active rest, and that time was the largest contributor to the recovery from DOMS (Hart *et al.,* 2005). While it was shown that sports massage did not improve recovery, the massage only consisted of five minutes of petrissage and effleurage, which may not have been a long enough period of time to optimise the effects of these techniques. To augment recovery, sports massage should be from 15 to 30 minutes long if it has been one hour or more after exercise, to facilitate physical recovery and implement both the primary and secondary effects of massage (Benjamin and Lamp, 1996; Findley, 2010). Therefore this underlines the need for massage to be longer than five minutes when trying to optimise recovery from high intensity exercise over a number of hours.

Contrary to the results found by Hilbert *et al.* (2003) and Hart *et al.* (2005), a study published by Andersen *et al.* (2013) explored the comparison of active rest and massage with passive rest, highlighting that both protocols had significant effects on recovery over passive rest. Participants took part in eccentric contractions of the upper trapezius muscles and received the sports massage and active rest recovery protocols 48 hours after exercise, when the effects of DOMS were experienced. Measurements of perceived soreness and pressure pain threshold (PPT) were taken at zero, 10, 20 and 60 minutes after the recovery protocol, with a significant reduction in perceived soreness ($p < 0.001$) and PPT ($p < 0.05$) across all time points after exercise, but no significant difference between the massage and active recovery (Andersen *et al.,* 2013). As this study discovered that sports massage had a significant effect when compared with passive rest on DOMS 48 hours after eccentric exercise, this highlights that beginning measurements of soreness 48 hours after the recovery protocol is the optimum time frame after exercise to discover if the recovery is effective in reducing soreness.

The studies above demonstrate that sports massage can be efficient in the reduction of muscle soreness after eccentric exercise, which can be explained by the physiological effects of sports massage that can restore mobility, increase muscle tone and stretch muscle fibres (Holey and Cook, 2011). As well as alleviating muscle soreness and restoring mobility, techniques such as effleurage can enhance venous flow and consequently improve the elimination of blood lactate through increased blood flow around the body (Holey and Cook, 2011).

2.5 THE USE OF SPORTS MASSAGE FOR BLOOD LACTATE REMOVAL

As lactate is transported in the blood, sports massage techniques such as effleurage can be used to enhance blood flow and consequently improve the removal of waste products (Hemmings *et al.,* 2000; SPS Ltd, 2003).

Many previous studies have compared different recovery interventions on blood lactate removal, such as the study published by Monedero and Donne (2000), which compared four 15 minute recovery protocols after a five kilometre maximal effort on a cycle ergometer. The protocols included passive, active, sports massage and a combined recovery, which consisted of cycling for 7.5 minutes at 50% of their VO_2 maximum and massage application for 7.5 minutes, in trained cyclists. It was discovered that active and combined recovery showed the most efficient removal of blood lactate after exercise, with combined recovery resulting in a better maintenance of performance (Monedero and Donne, 2000). Although massage was not found to be significantly beneficial when compared with active and combined recovery, the beneficial effect of the combined protocol implies that sports massage is an important intervention to incorporate into recovery, to enhance performance as well as diminish negative by-products from previous bouts of exercise. The sports massage techniques utilised in this study were effleurage, stroking and tapotement, which is similar to the study by Martin *et al.* (1998), questioning the validity of the results discovered due to the unsuitable use of the tapotement massage technique for the assessment of blood lactate removal. However, this study therefore demonstrated the potential benefits of massage to enhance recovery from exercise, although it may be most effective when used in combination with other recovery methods.

In conjunction with Monedero and Donne (2000), Martin *et al.* (1998) compared four sports massage techniques with active recovery, which consisted of cycling at 40% VO_2 maximum for 20 minutes, and passive rest after three consecutive 30 second Wingate anaerobic tests at maximal effort on a cycle ergometer. It was again discovered that active rest had the most significant effect on blood lactate removal, with no significant difference between the sports massage and passive rest protocols. The results highlighted that sports massage was not efficient in the promotion of blood lactate removal as the active rest was enough to maintain the metabolic rate after exercise to facilitate blood flow and lactate removal (Martin *et al.,* 1998). Although active recovery was the most beneficial recovery protocol in this study, the massage techniques used included tapotement and petrissage. These techniques may have an effect on physical and psychological stimulation and the mobility and length of fibrous tissue (Benjamin and Lamp, 1996; Holey and Cook, 2011), but they are not appropriate techniques for the enhancement of blood flow and successive removal of blood lactate, as they do not directly affect these physiological factors. As both Monedero and Donne (2000) and Martin *et al.* (1998) highlighted that active recovery showed significant effects on blood lactate removal, this suggests that a combination of effective sports massage techniques such as effleurage and active recovery can implement the most effective recovery.

In contrast to the studies by Martin *et al.* (1998) and Monedero and Donne (2000), Hemmings *et al.* (2000), only compared passive rest and sports massage recovery methods in eight amateur boxers after using a boxing ergometer. Similarly to Martin *et al.* (1998) and Monedero and Donne (2000), it was discovered that massage still had no significant effect when compared with passive rest. Both blood lactate removal and subsequent boxing performance were not improved through sports massage and it was suggested that blood flow was not increased enough to diminish the blood lactate levels (Hemmings *et al.,* 2000). Although massage had no significant effect on blood lactate levels and boxing performance, it was discovered that massage had a significant effect when compared to passive rest on perceived recovery. As the effleurage and petrissage massage techniques were applied to the back, legs, shoulders and arms, a possible psychological effect can explain the significance in reduced perceived recovery. Although massage was beneficial for this purpose, using effleurage and petrissage is not efficient in maintaining performance due to the lack of physical stimulation, suggesting more suitable techniques such as tapotement should be used to maintain boxing performance. Similarly to Martin *et al.* (1998), petrissage was also one of the techniques used for the removal of blood lactate and although it places a wringing effect on the muscle which stretches the tissue (SPS Ltd, 2003), blood flow is not directly affected. This provides and explanation as to why the blood flow was not increased enough to remove blood lactate and suggests a more appropriate massage technique such as light to deep effleurage should be used in future studies.

Contradictory to these findings, a study published by Wiltshire *et al.* (2010) found that sports massage actually impaired the removal of blood lactate after exercise. This study looked at 12 participants who used an isometric handgrip at 40% maximum voluntary contraction followed by three recovery conditions, passive and active rest and a sports massage including effleurage and petrissage. Wiltshire *et al.* (2010) found that lactate removal from the forearm was reduced during the sports massage condition due to a compromised forearm blood flow. As this study observed the lactate removal specifically within the deep veins that supplied the exercising muscle, a whole body measurement of the systematic blood lactate removal was not examined. This weakness within the study therefore doesn't asses the whole body effects of massage on blood flow and blood lactate removal and can provide an explanation as to why it was discovered that massage impaired the removal of blood lactate.

2.6 SUMMARY

The information in the above sub-topics explored the various recovery interventions that could be used to enhance the removal of blood lactate after high intensity exercise, with sports massage generally being shown to have no significant effect over active recovery (Martin *et al.,* 1998; Monedero and Donne, 2000). When the effects of sports massage on blood lactate removal were specifically analysed, some studies found that this recovery technique in fact had a detrimental effect on the blood lactate due to factors such as compromised blood flow (Wiltshire *et al.,* 2010). However, in many of the studies using sports massage as a recovery intervention, unsuitable massage techniques were used when researching into venous flow and removal of waste products. This introduces the requirement to utilise appropriate sports massage techniques that have been found to have influential effects on factors such as blood flow and cell permeability. This study was conducted with the aim of discovering if using effleurage as a specific sports massage technique was found to effect the removal of blood lactate after high intensity exercise. It was hypothesised that effleurage would result in an improvement in blood lactate removal when compared with passive rest.

CHAPTER THREE

METHODS

3.1 ETHICS

The study was approved by the ethics board at Cardiff Metropolitan University and all participants were provided with information before participating and gave voluntary written consent to participate. Participants also had the right to withdraw at any time during the study without providing a reason. Participant information sheet, informed consent forms and massage consent forms can be seen in Appendix A, B and C.

3.2 PARTICIPANTS

Nine participants, 7 males and 2 females, were recruited for this study with the average height, weight and age of 175.3 cm (± 7.1), 63.4 kg (± 6.7) and 19.9 years (± 1.8) respectively. A mix of males and females were used as a specific selection criteria was already outlined for participants, requiring athletes from particular track events who were already accustomed to high intensity exercise. As blood lactate responses to exercise are not gender specific, athletes from high intensity athletic events would therefore achieve similar levels of blood lactate from the exercise protocol. The participants were required to have been training and competing at University level for at least two years and were recruited from either Cardiff Metropolitan Athletics Club or Cardiff Amateur Athletics Club. The participants were competitors from distances ranging from 100 to 800m. Participants from these events were used due to the reduced recovery time between races when competing more than once in a day, therefore requiring effective recovery interventions. It was also required that the athletes had been injury free for at least two months before the study and were fit and healthy when commencing with the investigation. All the participants took part in both experimental protocols.

3.3 INSTRUMENTS

A Biosen analyser (C-Line Sport, EKF-Diagnostic, Barleban, Magdeburg, Germany) was used to measure the blood lactate levels throughout the study. A blood sample of 20 microlitres (ųl) was taken by a trained phlebotomist from the fingertip and placed into capillary tubes mixed with lysing stabilising agent. The samples were then analysed within 24 hours by the author of the study using the Biosen analyser. The Biosen was used due to it being more suitable for field testing due to the easy and rapid measurement of whole blood lactate (Davison *et al.,* 2000). Davison *et al.* (2000) reported that the Biosen is a valid and reliable blood lactate analyser with a coefficient of variation less than 3% over a range of blood lactate values. Sports massage was conducted on sports massage beds provided by the massage practitioners and a Mobile Metronome App (Mobile Metronome, Dot TK) was used to maintain the tempo of the effleurage strokes for all massage practitioners. A hypoallergenic mineral oil was used by all massage practitioners during the study. Anthropometric measurements were taken using the Harpenden wall mounted stadiometer (Holtain Ltd, Crosswell, Crymmych, Dyfed, Wales) for height which was measured to the nearest 0.1cm, and a digital weighing scales was used for body mass (SECA 770, Hamburg, Germany) and measured to the nearest 0.1kg.

3.4 EXPERIMENTAL PROCEDURE

All testing for this study was completed within the National Indoor Athletics Centre (NIAC) on a mondo track at Cardiff Metropolitan University to ensure validity of each experimental protocol. By using NIAC for all the experimental conditions in the study it allowed for ecological validity due to no external environmental factors affecting the 400m run or recovery interventions. A pilot study was conducted to determine whether any changes needed to be made to the protocol. After conducting the pilot study no changes were made as no issues with the protocol were discovered.

3.4.1 Warm Up

All participants took part in an adequate 10 minute warm up procedure before running the 400m. The warm up was standardised for each participant and consisted of a three minute self paced jog, followed by five minutes of drills such as high knee exercises and flick backs chosen by the individual participant, and two minutes of 40m strides. A maximum of three strides per participant was determined to minimise the build up of lactate and fatigue before participating in the 400m and each participant completed these three 40m strides within the final two minutes of the warm up. The participants were then required to run the 400m as fast as possible, without any knowledge of their time and running alone to ensure validity across both 400m runs. A 400m run was used in this study due to the specificity of the event to the participants and the length of the event, usually lasting from 50 up to 70 seconds, which utilises the anaerobic glycolytic energy pathway resulting in an accumulation of lactate in the blood (McArdle *et al.,* 2001).

3.4.2 Blood Lactate Measurements

Blood lactate levels were taken four times during each testing procedure by a trained phlebotomist from Cardiff Metropolitan University. Blood lactate levels were taken after the warm up immediately before the 400m, 2 minutes after the 400m, immediately after the recovery protocol and once again 20 minutes after the recovery protocol. A quantity of 20ɥl of blood was taken from the same fingertip of the participant by a trained phlebotomist and was then analysed using the Biosen blood lactate analyser.

3.4.3 Recovery Protocols

Participants took part in both recovery protocols using a randomised crossover design. The recovery interventions took place after the participants ran the 400m and after their blood lactate levels were taken for the second time. The recovery protocols consisted of passive rest and sports massage. The sports massage intervention used effleurage, using flat hand and the V technique. These techniques were chosen due to the ability to easily alter depth whilst also maintaining reliability between massage practitioners. All sports massage therapists in the study were qualified and insured Level 4 practitioners with an SPS Diploma in Sports Massage and were familiar with the chosen techniques. Sports massage was conducted upon the calves and hamstrings of both legs for 20 minutes in total, five minutes on each part of the limb. Flat hand and V were applied with the rhythm of a metronome to 65 beats a minute which ensured all sport massage practitioners applied the techniques to the same rhythm. The massage practitioners used the V technique within the first and last minute of the massage on each body part, with flat hand being used for the remaining three minutes. This was then repeated for all four body parts being massaged. Practitioners continued to ask throughout the massage about the participants comfort and pain sensation with depth being dictated by the participants, and all participants completed a client assessment form to ensure they were suitable to receive a massage before commencing with the recovery protocol. All massage practitioners used the same techniques and practiced each technique with the same hand positions. During passive rest, which served as the control protocol, the participants were in a seated position for 20 minutes. During the final 20 minutes, before the final blood lactate measurement, participants were instructed to do what they would usually do in a competitive environment, either using an active recovery which consisted of jogging, or a continued passive rest. The recovery protocols (sports massage and passive rest) were the independent variables during this study with the blood lactate being the dependant variable.

3.5 DATA ANALYSIS

The Biosen C-Line Sport was used for blood lactate which analyses values from the range of 0.5 to 40mmol/L. The data collected from the Biosen blood lactate analyser was collected originally as raw data and then entered into the Statistical Package for the Social

Sciences 20.0 software (SPSS Inc., Armonk, NY). A paired samples t-test was used to discover if there was a significant difference between the blood lactate values in the post warm up and post 400m blood lactate values between both weeks. The paired t-test was also used to discover if there was a significant difference between the blood lactate values of the post warm up and post 400m protocols for both weeks. The paired samples t-test compared two samples from the same group of participants (O'Donoghue, 2012). An independent samples t-test was used to compare the blood lactate values of the active and passive rest during the final 20 minutes of data collection on both weeks. The independent samples t-test compares values from two different groups to discover if there was a significant difference between these groups (O'Donoghue, 2012). The two way repeated measures analysis of variance (ANOVA) test was used to highlight any significance between massage and passive rest protocols, which compared the results of three or more variables within the same group of individuals (O'Donoghue, 2012). The mean values (±SD) of the groups were calculated for each recovery protocol and the statistical significance value was $p < 0.05$.

CHAPTER FOUR

RESULTS

4.1 PARTICIPANT INFORMATION

A total of nine participants, 7 males and 2 females, were used in this study. Table 4.1 demonstrates the height, weight and age.

Table 4.1 Mean (± SD) height (cm), weight (kg) and age (years) of each participant.

Height	Weight	Age
175.3 ± 7.1	63.4 ± 6.7	19.9 ± 1.8

Although the study consisted of a mix of males and females the small SD values show the little variation in the participants height, weight and age due to the specified selection criteria for participants.

4.2 PARTICIPANT BLOOD LACTATE LEVELS

4.2.1 Blood Lactate Response to Exercise

A 400m run was used in this study to elicit a high blood lactate response in all participants and a paired t-test was used to discover if values significantly increased from the post warm up to the post 400m measurements across all trials. The paired t-test revealed a significant difference ($p < 0.05$) between the measurements and table 4.2 shows the mean blood lactate values (±SD) for post warm up and post 400m.

Table 4.2 Mean (±SD) blood lactate values (mmol/L) post warm up and two minutes post 400m.

Post Warm Up	Post 400m
3.30 ± 1.1*	11.92 ± 2.3*

*significant difference $p < 0.001$

4.2.2 Weekly Blood Lactate Values

Table 4.3 and 4.4 highlight the mean (±SD) values of the post warm up and post 400m blood lactate values of participants between week one and week two. A paired samples t-test was used to distinguish if there was a significant difference between both the post warm up and post 400m blood lactate values from week one to week two. The test discovered no significant difference ($p > 0.05$) between the values of both blood lactate measurements, showing the consistency of effort and blood lactate values achieved throughout the study and indicated that no learning effect had taken place.

Table 4.3 Mean (±SD) blood lactate values (mmol/L) for participants post warm up in week one and week two.

Week 1	Week 2
3.32 ± 1.1	3.29 ± 1.1

No significant difference $p > 0.05$

Table 4.4 Mean (±SD) blood lactate values (mmol/L) for participants post 400m in week one and week two.

Week 1	Week 2
11.95 ± 2.1	11.90 ± 2.6

No significant difference $p > 0.05$

4.2.3 Post Recovery Blood Lactate Values

The 20 minutes post recovery lactate values were also analysed using an independent sample t-test to compare the active recovery and passive recovery blood lactate values. Table 4.5 highlights the mean (±SD) values for the active and passive 20 minute recovery post massage or passive rest. Although a larger number of participants did active rest during the 20 minutes, there was no significant difference ($p > 0.05$) between the active and passive recovery blood lactate values.

Table 4.5 Mean (±SD) blood lactate values (mmol/L) for active and passive recovery during the 20 minutes post massage and passive rest intervention.

Active Recovery	Passive Recovery
3.18 ± 1.7	4.19 ± 0.9

No significant difference $p > 0.05$

4.2.4 Blood Lactate Levels Between Massage and Passive Rest

Mean blood lactate (±SD) values for all four measurements throughout the testing are shown in table 4.6. A two way repeated measures ANOVA revealed a significant difference ($p < 0.05$) across the time, revealing that the blood lactate levels decreased significantly after both recovery interventions.

Table 4.6 Mean (±SD) for blood lactate levels (mmol/L) measured during the study.

	Post Warm Up	Post 400m	Post Recovery	20 minutes Post Recovery
Passive Rest	3.29 ± 1.09[a]	11.90 ± 2.64[b]	7.86 ± 2.62[b,c]	3.59 ± 2.04[c]

	Post Warm Up	Post 400m	Post Recovery	20 minutes Post Recovery
Effleurage	3.32 ± 1.09[a]	11.95 ± 2.10[b]	6.97 ± 2.38[b,c]	3.22 ± 1.10[c]

[a]significant difference $p < 0.001$
[b]significant difference $p < 0.001$
[c]significant difference $p < 0.001$

Figure 4.1 illustrates the blood lactate values at all measurement times across the study. No significant difference ($p > 0.05$) was discovered within the intervention-time analysis. This demonstrates that there was no significant difference between the values of pre to post recovery between the massage and passive rest interventions.

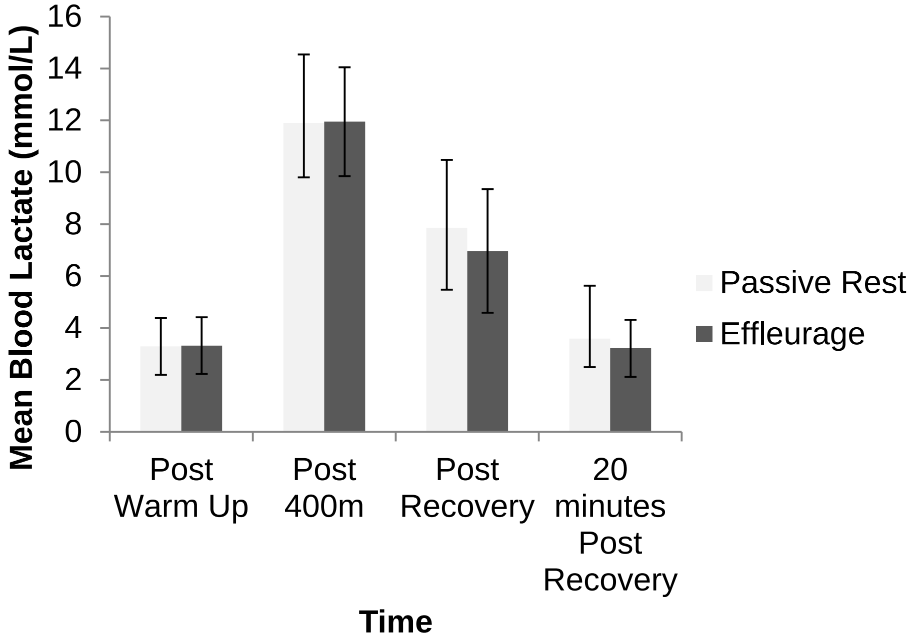

Figure 4.1 Mean (± SD) values for each blood lactate measurement for both effleurage and passive rest.

4.3 DATA ANALYSIS

Analysis of the blood lactate levels throughout the study revealed that 20 minutes of both passive rest and effleurage significantly decreased blood lactate values from post 400m to post recovery intervention values. Although there was a significant decrease during the time analysis, no significant differences were found between the blood lactate values of the passive rest and effleurage protocols. This demonstrated that effleurage did not have a significant effect on the blood lactate values after high intensity exercise when compared with passive rest. As the SD values were large in the post 400m and post recovery blood lactate measurements this implies that there was a large variation between participants which may be down to the individualised response seen between participants (see Appendix D).

CHAPTER FIVE

DISCUSSION

5.1 PARTICIPANTS

The current study aimed to discover if there was a difference in the blood lactate values between sports massage, utilising effleurage, and passive rest recovery interventions after high intensity exercise. Participants in this study were required to run 400m at their maximum speed to obtain high levels of blood lactate that would be replicated in their athletic event. A specific selection criteria was outlined for participants, and similar to previous studies (Martin *et al,* 1998; Monedero and Donne, 2000), a specific sporting population was used to explore the effects of massage on blood lactate levels after high intensity exercise. Using a specific population of athletic individuals allowed for reliability within both the anthropometric measurements and the blood lactate response to exercise, due to the athletes being accustomed to running 400m and exerting a maximal effort against the anaerobic lactic acid response to exercise. The studies (Martin *et al,* 1998; Monedero and Donne, 2000) using specific sports allow a useful opportunity for replication of recovery in a competitive environment, which poses an advantage over studies that have used a generally healthy population to explore the use of massage for blood lactate removal. Using a similar high intensity exercise stimulant and athletes who experience high levels of blood lactate during training or competition allowed for ecological validity throughout the current study, and can therefore be applied to an athletes training and recovery programme. Studies such as those by Ogai *et al.* (2008), Wiltshire *et al.* (2010) and Cé *et al.* (2013) used the general healthy population to examine the effects of massage on blood lactate after exercise, and although the results were similar to those seen in a sport specific study, they would not be applied to any specific sporting individuals due to the non-specificity in the choice of participants. The current study can therefore be applied to track events that require the utilisation of various recovery strategies for improved physiological restoration over shorter periods of time between competitions.

5.2 BLOOD LACTATE RESPONSE

5.2.1 Blood Lactate and High Intensity Exercise

The accumulation of blood lactate is a response of a substrate produced from the anaerobic glycolytic energy system utilised during high intensity exercise that lasts from between 10 seconds up to five minutes (Gorostiaga *et al.,* 2010; Sjokvist *et al.,* 2011). Table 4.2 shows that the 400m run in this study was enough of a stimulation to elicit a significant response in blood lactate compared with pre exercise values. Similar results were seen in the studies of Martin *et al.* (1998), Hemmings *et al.* (2000) and Ogai *et al.*

(2008), where blood lactate values were measured both immediately before and after the exercise protocol, highlighting that exercise bouts of 5 seconds up to 2 minutes were enough to build an accumulation of lactate in the blood. Although the exercise used in these studies produced a significant increase in blood lactate, they do not support the importance of optimising recovery strategies in a competitive environment due to the use of scientific testing, such as the Wingate test on a cycle ergometer. However, this current study aimed to replicate the stresses an athlete would experience during competition to discover if an increase in blood lactate could be reduced through specific recovery strategies. As this study showed a 27% increase in the blood lactate values from before to after the 400m, it is important for athletes and coaches to realise the importance of optimising recovery strategies to minimise the detrimental effects of blood lactate accumulation.

5.2.2. Weekly Blood Lactate Values

The current study used a randomised crossover design to allow for validity between participants over both weeks of the data collection. No significant difference was discovered between the weekly blood lactate data of all participants, as can be seen in table 4.3 and 4.4, demonstrating consistency within both the exertion during the exercise protocol and blood lactate values at all time frames. Similar designs were used by Hemmings *et al*. (2000) and Monedero and Donne (2000) where participants returned to take part in the experimental protocol at least twice over a number of weeks. A randomised crossover design was used over a number of weeks in this study to minimise any advantages between groups, with participants serving as their own control (Page, 2012; Connelly, 2014). As participants underwent the recovery protocols on different weeks, this allowed control for the variables in the study and can account for the consistency within the blood lactate responses to exercise. As well as the control for the variables from week one to week two, it can be assumed that no learning effect has taken place due to the consistency within both performances over the number of weeks.

5.2.3 Active and Passive Recovery

Passive rest and sports massage were the recovery methods utilised in this study to discover if blood lactate values differed between recovery interventions after high intensity exercise. Along with both of these recovery protocols, during a 20 minute period after the initial recovery, participants commenced either an active or continued passive recovery before measuring blood lactate for the final time. Although more participants used active recovery during these 20 minutes due to this option being self selected, no significant difference was found between the active and passive recovery blood lactate values. Although the current study did not specify that active recovery should be incorporated, participants were instructed to commence with whatever recovery they would usually do after competition. As active recovery can maintain elevated levels of metabolic rate (Martin *et al*., 1998) this promotes increased lactate oxidation and consequently clearance from the body. More participants utilised an active recovery during the final the 20 minutes of the protocol, demonstrating that athletes are more likely to use a combination of recovery methods that include an active recovery. This combination of recovery interventions is in agreement with the study conducted by Monedero and Donne (2000), which discovered a combined recovery of active rest and sports massage showed significant decreases in blood lactate values. This provides an explanation as to why combining active recovery with sports massage can elicit greater effects on the removal of blood lactate after high intensity activity during competition. Taking this into consideration, this information provides the knowledge for athletes and coaches to include a combined recovery during competition to obtain a faster recovery from high intensity exercise, and maintain the ability to perform repeated bouts of exercise when the blood lactate response is high. Although the study by Monedero and Donne (2000) showed that a combined recovery showed a significant decrease in blood lactate levels, more research is necessary to determine whether combining sports massage with other recovery interventions can significantly decrease blood lactate levels after exercise. This requires more extensive research to discover what strategy is best for athletes to adapt when optimising their recovery from high intensity exercise and minimising the detrimental effects of lactate within the body.

5.2.4 Sports Massage and Passive Rest Recovery Interventions

The main finding in this study was that massage had no significant effect on blood lactate removal when compared with passive rest. The hypothesis in the current study can therefore be rejected due to there being no difference between the passive rest and sports massage recovery interventions. Previous studies have compared recovery interventions such as active, combined and sports massage for recovery (Martin *et al.,* 1998; Monedero and Donne, 2000; Wiltshire *et al.,* 2010; Cé *et al.,* 2013), but only one previous study has specifically compared sports massage and passive rest (Hemmings *et al.,* 2000). Although the study by Hemmings *et al.* (2000) only compared passive rest and sports massage, a variation of massage techniques were utilised, rather than specifically focusing upon the effects of one technique. The current study specifically analysed the effects of one sports massage technique to discover if massage was more beneficial for the removal of blood lactate. Effleurage was the chosen sports massage technique as it can improve venous and lymphatic flow whilst removing any harmful by products such as chemical irritants (Holey and Cook, 2011). Monedero and Donne (2000) compared four recovery interventions, active, combined, massage and passive rest, on blood lactate levels, and highlighted that massage was more beneficial for the blood lactate removal than passive rest. Although the removal of blood lactate in both active and combined was significantly higher than both massage and passive rest, massage was not found to have any detrimental effect on the removal of blood lactate after exercise. Effleurage was also one of the sports massage techniques utilised in the study by Monedero and Donne (2000), which emphasises the advantageous effects this technique can have on blood flow and removal of waste products. As effleurage can be applied superficially, for reflexive values, and deeply for mechanical effects, the rhythmic sweeping movement of the technique allows for the movement of fluid within the tissues (Findlay, 2010; Holey and Cook, 2011). Effleurage has many physiological effects that could also aid the removal of blood lactate, with the stroking movement of this technique maintaining pressure towards the heart and consequently improving venous flow (SPS Limited, 2003).

Cé *et al.* (2012) similarly discovered that deep massage had more beneficial effects on the removal of blood lactate after exercise than stretching, superficial massage and passive rest. Effleurage was also used in this study, and was found to have favourable effects on the lactate kinetics over superficial massage, which consisted of myofascial release with stretching along the direction of the muscle fibres (Holey and Cook, 2011). The study by Cé *et al.* (2012) is therefore in concurrence with the current study, highlighting that although sports massage does not have a significant effect on the removal of blood lactate when compared with passive recovery, it provides a more effective recovery technique to aid the removal of blood lactate after high intensity exercise.

Contradictory to these findings, Wiltshire *et al.* (2010) reported that sports massage in fact impaired the removal of blood lactate after strenuous exercise due to a compromised blood flow, as a direct result of the compression of the muscle tissue. Although blood lactate removal was impaired by massage in this study, a contradiction between both the surface area of the massage and the choice of blood lactate measurements can be observed between Wiltshire *et al.* (2010) and the current study. As a significantly larger muscle mass was examined in the current study during high intensity fatiguing exercise, comparisons cannot be made due to the specificity of the rhythmic static contractions of the forearm in the study by Wiltshire *et al.* (2010). The current study also examined whole blood lactate values at all time frames across the study, whereas Wiltshire *et al.* (2010) only observed the lactate efflux from the forearm venous flow. Although this is considered a more specific and direct technique of assessing blood lactate values after exercise due to the catheter being inserted directly into the exercised muscle (Wiltshire *et al.,* 2010), a whole blood measurement is more applicable to competitive environments as a generally larger muscle mass is used during exercise across many sporting events.

The positive effects of massage discovered in the current study emphasise the importance of incorporating various recovery interventions after high intensity exercise to maximally improve the removal of blood lactate. This can be seen in the study by Monedero and Donne (2000) where a combined recovery using both massage and active rest had the most significant effect on the removal of blood lactate after exercise. Utilising massage for a given amount of time can therefore improve recovery by allowing lactate to pass into the interstitial space and blood at a faster rate, where it can be removed from the muscle and buffered by nicotinamide adenine dinucleotide (NAD^+) to eventually form ATP (McArdle *et al.,* 2001). It has been documented that during exercise that increases the levels of arterial lactate, the myocardium takes up and utilises the lactate via myocardial oxidative metabolism (Stanley, 1991). This utilisation of lactate by the myocardium emphasises the importance of removing the lactate from the muscles into the blood to prevent a harmful accumulation of lactate within the muscles, where it can negatively effect the calcium binding during muscular contraction (Wilmore and Costill, 2004). From this information, sports massage could be seen to have detrimental effects on lactate levels within the blood, as the compression of muscle tissue and increase in blood flow could amplify the levels of lactate when taking a whole blood measurement. The improvement in venous flow brought on by the effleurage massage technique can provide a possible explanation as to why effleurage did not show a significant effect on blood lactate values when compared with passive rest. Although the improvement in venous flow can aid with the removal of blood lactate from the muscle, the consequent flushing of the by-product into the blood could show a larger value within the whole blood lactate measurement. Although sports massage could have therefore be seen to have detrimental effects on blood lactate levels in a whole blood measurement, utilising an optimum time frame for blood flow to be increased enough to allow the transportation and removal of lactate is important. This study used a 20 minute intervention and discovered that blood lactate values had decreased significantly compared to the post exercise lactate levels. Similarly to this, Franchini *et al.* (2009) highlighted that a 15 minute recovery between high intensity judo was a long enough interval for a full recovery from the negative effects of blood lactate. This supports the current study as similar time frames were used for the recovery interventions which demonstrated a beneficial effect for the removal of blood lactate and recovery from high intensity exercise.

5.3 PRACTICAL IMPLICATIONS

The current study employed specific selection criteria for participants to allow for a real life replication of the lactate response from high intensity exercise and recovery interventions employed by athletes during competition. The results from this study concluded that there was no significant difference between the passive rest and sports massage recovery interventions, highlighting that sports massage did not elicit a greater response for the removal of blood lactate. This implies that athletes should not utilise sports massage as the only recovery intervention after high intensity exercise, but the combination of sports massage and other recovery interventions such as active recovery may allow athletes to optimise recovery between events.

While massage was not seen to have more beneficial effects on the removal of blood lactate when compared to passive rest, utilising a 20 minute time frame for the recovery was enough to significantly decrease the blood lactate levels from post exercise values to post recovery values. This significant reduction in this time frame is important for coaches as it underlines that even a 20 minute recovery intervention can decrease the levels of blood lactate, and could prevent a reduction in the performing abilities of the athlete. The current study outlined an optimum time frame for the reduction of blood lactate levels and suggested a requirement for the combination of recovery interventions to optimise athletic recovery due to the non-significant difference between sports massage and passive rest.

5.4 LIMITATIONS

This study utilised effleurage as a massage technique to examine the effects of sports massage on blood lactate removal after high intensity exercise. As effleurage is a recognised technique for post event massage due to it aiding with the removal of waste products and physical recovery (Benjamin and Lamp, 1998; Holey and Cook, 2011), it has been utilised in a number of studies for the removal of blood lactate (Martin *et al.,* 1998; Hemmings *et al.,* 2000; Monedero and Donne, 2000; Wiltshire *et al.,* 2010). Although effleurage is the most utilised sports massage technique for post event massage, it does not represent the only sports massage technique available to promote recovery after exercise. The current study, along with previous studies assessing the effects of massage on blood lactate (Martin *et al.,* 1998; Hemmings *et al.,* 2000; Monedero and Donne, 2000; Wiltshire *et al.,* 2010) have only used one massage technique, signifying the need for future studies to compare different massage techniques for the removal of blood lactate. As techniques such as compressions, which flush any waste products from the muscle cells and deactivate hypertonic muscles (Holey and Cook, 2011), can elicit an improvement in post exercise recovery, a comparison could be made in future studies to discover which technique is most efficient in promoting recovery.

Another potential issue with the study is the individualised response to high intensity exercise between participants and following sports massage and passive rest interventions. While the participants used in the study were specifically track runners from 100 up to 800m events, different fitness statuses and lactate thresholds can be seen within participants, which is represented by the large SD values for post 400m and post recovery blood lactate values in figure 4.1. This can consequently have an effect on the significance of massage due to different participants achieving various levels of blood lactate after the 400m exercise protocol. To reduce the effects of varying blood lactate responses to exercise, lactate profiling of all participants could be used to establish a number of athletes with similar lactate thresholds. This technique was utilised in the study by Greenwood *et al.* (2008) to determine recovery intensities for each participant, which was found to be highly efficient in determining which percentage of the lactate threshold was most effective for the removal of blood lactate. Using specialised lactate profile equipment could therefore help determine participants with similar lactate responses to high intensity exercise and reduce the individualised effects seen in this study. As well as using lactate profiling, a larger number of participants would provide improved statistical power within the results as well as improving the validity of the study (Page, 2012). A larger sample size would therefore minimise the possibilities of an individualised response as a larger sample size would allow for the comparison of data within a larger group of individuals.

If this study was to be conducted again, more than one massage technique would be used to compare the use of sports massage with passive rest for the removal of blood lactate. As a limitation of this study was the fact that only one sports massage technique was used, it did not explore the variety of techniques available for optimising physiological recovery between events. For instance, compressions are a recognised sports massage technique for physical restoration after exercise, and should be incorporated into future studies that further explore recovery interventions to enhance blood lactate removal after high intensity exercise.

5.5 FUTURE RESEARCH

Taking these limitations into consideration, future research within this area should aim to discover if a combination of recovery techniques optimises the reduction of blood lactate when compared to only using one recovery technique. Employing a variety of massage techniques such as effleurage, compressions and dermal lifting which improve venous flow, aid the removal of fluid from the tissue and increases circulation in the skin capillaries (SPS Limited, 2003), can help outline which technique is the most effective for the removal of blood lactate. Along with using a variety of massage techniques, combining recovery methods such as active recovery with sports massage could determine the best interventions for athletes and coaches to incorporate into competition and training.

CHAPTER SIX

CONCLUSION

6.1 CONCLUSION

In conclusion, sports massage using the specific effleurage technique did not show a significant difference in blood lactate values when compared with passive rest, which is similar to many previous studies (Martin *et al.,* 1998; Monedero and Donne, 2000; Hemmings *et al.,* 2000). This study aimed to compare the use of two popular recovery interventions after a 400m run within track athletes, and highlighted that sports massage did not show a significant effect on the blood lactate levels compared to passive rest. Comparing sports massage and passive rest therefore highlighted that effleurage was not a more beneficial recovery technique for the removal of blood lactate after high intensity exercise. Although there was no significant difference between massage and passive rest, blood lactate levels after the recovery protocol were significantly reduced. These findings highlight that a 20 minute massage protocol is enough to improve the removal of blood lactate after high intensity exercise, with the removal being optimised with a combined inclusion of active recovery after the initial sports massage. Employing sports massage and passive rest in this study allowed for the comparison of recovery methods utilised by athletes in competitive environments to determine which method would be most beneficial on the removal of blood lactate. This gave a practical point of view for athletes and coaches as to which recovery interventions were most important to apply when looking to optimise recovery between high intensity events. Although massage did not elicit a beneficial effect on the blood lactate response when compared with passive rest, future research should explore a comparison of sports massage techniques that could optimise blood lactate removal, to distinguish which technique would be more advantageous for athletes recovering from high intensity exercise. Athletes should not neglect the use of sports massage for recovery from high intensity exercise, as including this method in the recovery between events could potentially optimise blood lactate removal and aid with the maintenance of performance between multiple events.

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APPENDICIES

APPENDIX A
INFORMED CONSENT SHEET

CARDIFF METROPOLITAN UNIVERSITY
INFORMED CONSENT FORM

CSS Reference Number: st20019889

Title of the project: Do different sports massage techniques improve the removal of blood lactate after exercise in middle distance runners?
Name of Researcher: Charlotte Leah Bitchell

Participant to complete this section: Please initial each box.

1) I confirm that I have read and understand the information sheet dated ______ for this evaluation study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2) I understand that my participant is voluntary and that it is possible for me to stop participating at any time, without giving a reason. ☐
3) I also understand that if this happens, our relationship with Cardiff Metropolitan University, or our legal rights will not be affected. ☐
4) I understand that the information from the study may be used for reporting purposes, but I will not be identified. ☐
5) I agree to participate in this study. ☐

Name of participant: ________________________

Signature of participant: ___________________ Date: __________

Name of person taking consent: ______________________

Signature of person taking consent: ________________ Date: __________

APPENDIX B
PARTICIPANT INFORMATION SHEET

CSS Reference Number: 14/5/25U

Title of study: A comparison of the effects of compressions and effleurage on blood lactate removal in track athletes after exercise.

<u>Participant information sheet.</u>

This document will provide information on:

1) The background and research aim of the study
2) Your role in the study
3) Requirements
4) Possible risks
5) Possible benefits from the study
6) How the data will be collected
7) How the data will be used

Background and Research aim

Sports massage is widely utilised by different athletes and can provide beneficial performance outcomes. Previous research has discovered that post-exercise massage can enhance the recovery and removal of blood lactate after exercise when compared to passive rest. As massage is proposed to enhance blood flow, blood lactate can be transported around the body and removed at a faster rate, decreasing the fatiguing effects blood lactate has upon the body.

The aim of this study is to discover if different massage techniques improve the removal of blood lactate after strenuous anaerobic exercise. This study will aim to discover the best massage technique to use to optimise recovery from anaerobic exercise which causes the build up of blood lactate.

Your role in the study

If you decide to volunteer to take part in this study you will be expected to attend three sessions over a number of weeks that will last no more than two hours. You may not be required to stay for the whole duration. You will need to take part in a 400 m sprint in the National Indoor Athletics Centre (NIAC) before taking part in any of the recovery protocols. You will be required to do three 400 m sprints in total on separate days for this study, which will be separated by at least 48 hours. Your blood lactate levels will be taken before and after the 400 m, after the recovery protocol and again 20 minutes later. This will also be done in NIAC by trained phlebotomists from the Cardiff School of Sport who will take a blood sample from your index finger. You will take part in three different experimental controls, two of which will include a sports massage. The sports massage protocols will consist of one 20 minute sports massage using effleurage and a 20 minute massage using compressions, and the control protocol will be a 20 minute period of passive rest.

Requirements

To take part in this study it is required that you are injury free both two months before and at the start of the study. It is required that you have been running competitively for at least two years and are either a member of Cardiff Metropolitan Athletics Club of Cardiff Amateur Athletics Club. You must also be between the age of 18 and 26.

Possible Risks

As part of the study you will be required to take part in a 400 m maximal sprint which will be strenuous but should not put you at risk. A suitable warm up should be conducted before participating in the 400 m to minimise the risk of injury. Blood lactate will need to be taken four times for each experimental condition, therefore requiring withdrawal of blood from your fingertip. This could be quite invasive and if you should choose to voluntarily participate, all measurements will be clearly explained and outlined before beginning the study.

Possible Benefits

The information gathered from the experimental protocols will determine what techniques are best for removal of blood lactate and whether massage has a benefit over passive rest. This will be beneficial to you as a performer as sports massage could then be incorporated into any post event routine if it is found to have beneficial effects.

How the data will be collected

Your blood lactate levels will be collected by a trained phlebotomist from the Cardiff School of Sport from your finger four times during the day of data collection. Your blood lactate levels will then be measured through the Biosen analyser in NIAC. This data collection will allow a comparison of blood lactate levels when using sports massage as a recovery method after strenuous exercise.

How the data will be used

The data collected will be used and presented in the final results of the study. Your personal information will remain anonymous and will be used alongside the data of other participants.

As a *voluntary* participant you have a right to withdraw from the study at any given time without providing a reason why.

Protection of your privacy

All the personal information you have provided will remain anonymous throughout the study and will not be shown in any written notes or documentation. Any personal information provided by you will follow the guidelines of the Data Protection Act (1998) and remain confidential throughout.

Contact

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APPENDIX C
MASSAGE CONSENT FORM

Client Assessments Date:

Preliminary Information

Forename: Surname:

Title: DOB:

Male/Female: Telephone No.:

GP Address/Tel.no.: GP Name:

How are you feeling today?

Have you had your blood pressure taken?

Reading –

When –

By whom –

Are you taking any medication?

Have you had any surgery in the past 6 months?

Are you subject to any medical condition?

Do you have any allergies?

Anything else of relevance that I should be aware of?

Do you experience any pins and needles?

Do you experience any loss of strength?

Decision:

Aims of massage:

Client Signature: Date:

APPENDIX D
PARTICIPANT DATA

Participant Raw Anthropometric Values

Height (cm)	Weight (kg)	Age
182.2	68.3	18
185.0	70	21
172.5	68.7	21
181.0	72.4	23
177.8	60.1	18
167.6	56.2	19
175.2	63.4	18
173.0	56.5	21
163.0	55	20

Participant Raw Blood Lactate Values

Effleurage			
Post Warm Up	**Post 400**	**Post Massage**	**Post 20mins**
2.48	9.09	5.30	3.54
3.24	13.22	9.05	4.57
3.87	12.24	5.76	2.03
5.34	15.67	7.13	3.82
1.88	11.13	5.05	1.99
2.74	11.36	7.13	2.54
3.97	13.84	12.25	4.62
4.04	11.65	6.15	3.88
2.30	9.33	4.87	1.95

Passive Rest			
Post Warm Up	**Post 400**	**Post Rest**	**Post 20mins**
3.57	11.03	8.10	1.69
2.04	14.22	8.04	1.50
4.17	11.14	6.59	2.17
5.16	16.85	12.05	5.58
1.62	9.04	6.14	3.10
3.87	13.88	11.96	7.85
2.71	8.50	7.75	2.84
3.03	11.15	5.18	3.46
3.44	11.25	4.92	4.09