Massey University
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The Effect of the Recovery Duration between Warm-up and Competition on Physiological and Psychological Markers in Well-Trained Football Players

Submitted by Terry O'Donnell to Massey University as a thesis for the degree of a Master of Science in Exercise and Sport Science (February, 2013)

I certify that all material in this dissertation which is not my own work has been identified and that no material is included which has been submitted for the granting of a degree by this or any other university institution.

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Abstract

Purpose: Football players at the elite level are required to cease warming up 20 minutes prior to matches commencing (Blatter & Linsi, 2003). Since a duration of 15-20 minutes may cause muscles cooling, this time period could be problematic for athletic performance (Bishop, 2003a). Therefore the aim of this research study was to investigate the effect of varied recovery durations post warm up on physiological, perceptual and performance measures of football players during the Loughborough Intermittent Shuttle Test (LIST).

Methods: Thirteen male football players completed five assessment sessions; a graded exercise test (GXT) to maximal functional capacity, a baseline assessment for athletic performance (sprint, agility and vertical jump), and three experimental trials. After completing a standard active warm up, the experimental trials required participants to passively recover for either 5, 10 or 20 minutes before performing assessments of sprinting, vertical jump and agility. Thereafter, participants completed a 90 minute intermittent shuttle protocol (LIST). Heart rate (HR), blood lactate (BLa), the feeling scale (FS), felt arousal scale (FAS) and rating of perceived exertion (RPE) were collected at regular intervals throughout the LIST. All subjects completed the test on 3 separate occasions under each recovery condition.

Results: Sprint performance following a 5 minute recovery was significantly slower than the baseline performance assessment (2.52 ± 0.12s *cf.* 2.43 ± .09s $P < 0.016$). Although both sprint and agility performance showed a trend towards being negatively affected by a 20 minute recovery duration (P = 0.032 and 0.031 respectively), participants vertical jump typically improved following only 10 minute recovery duration. Participants were less aroused and experienced lower levels of pleasure (FAS and FS) throughout testing following the 20 minute recovery duration (1.50 ± 0.97 *cf.* 2.80 ± 1.14, and .50 ± 1.88 *cf. 3*.17 ± 1.33, $P < .05$). When investigating the physiological and perceptual response during the LIST, the recovery duration did not significantly influence participants' HR, BLa, RPE or performance response.

Conclusion: This study would suggest that a recovery period of 10 minutes post warm up may improve FAS, FS and VJ during exercise. However, ambiguous findings observed for BLa failed to provide physiological data to support these findings. The small sample size is the primary reason for these equivocal results. Future research should consider the effect of a larger sample size, inclusion of sport-specific skills and mechanisms for maintaining temperature during this interim period.

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Chapter 1: Introduction

Pre-event warm ups (WU) have become commonplace in the athletic arena despite poor understanding of reasoning behind the practice (Bishop, 2003a). Research has produced contrasting opinions on what constitutes an ideal WU for maximizing subsequent performance (Jones, Koppo, & Burnley, 2003; Behm & Chaouachi, 2011; Brunner-Ziegler, Strasser, & Haber, 2010). WU routines can be generally split into passive and active categories with additional stretching including static and dynamic components. In terms of practical application for the sporting population, active warm up is more commonly performed and the most likely to elicit the desired improvements (Bishop, 2003b). An increase in muscle temperature, either actively or passively, has been postulated to be the primary mechanism for the observed advantages associated with implementing a WU (Bishop, 2003a; West, et al., 2012).

An important factor in a successful WU is increasing the core and muscle temperature of participants, however active and passive WU achieve this through different methods. Active WU uses physical exercise to gain these temperature related performance improvements. The key mechanisms through which performance enhancement is accomplished are a rightward shift in both the force velocity curve and oxyhaemoglobin disassociation curve, vasodilation of blood vessels supplying working muscles, reduced muscle stiffness and improved conduction of nerve signals (Gray & Nimmo, 2001; Cè, Margonato, Casasco, & Veicsteinas, 2008).

In addition to temperature enhancements, active WU is also able to gain other physiological advantages including a blunted lactate response (Gray, Devito, & Nimmo, 2002), post activation potentiation (Tillin & Bishop, 2009) and maximizing oxygen consumption utilization (McCutcheon, Geor, & Hinchcliff, 1999). Another possible avenue for improving performance is through mental benefits such as raising alertness and awareness (Bishop, 2003a). Active WU has produced performance improvements in exercise ranging from short power activities through to endurance events (Fradkin, Sherman, & Finch, 2004; Hajoglou, Foster, De Koning, Lucia, Kernozek, & Porcari, 2005; Fradkin, Zazryn, & Smoliga, 2010).

The effectiveness of a WU is largely dependent upon a series of inter-related factors. These include the intensity, the duration and the amount of recovery time between WU and competition. These variables will be dictated by the fitness level of the athlete, the length and type of event being prepared for, and the requirements of each sports pre-match routine (Mujika, de Txabarri, Maldonado-Martín, & Pyne, 2012). Football in particular has very strict requirements regarding WU protocols prior to competition. At international competitions there is an extensive pre-match ceremonial routine meaning that players must cease WU 20 minutes prior to the match commencing (Blatter & Linsi, 2003). Accordingly, the elevation in core and muscle temperature that is elicited from an active WU may not be maintained through to the commencement of competition, and as such it may be speculated that performance may be impaired at the onset of exercise (Saltin, Gagge, & Stolwijk, 1968).

Research investigating the link between recovery duration following WU and performance is scarce with only selected sports being considered (Zochowski, Johnson, & Sleivert, 2007; West, et al., 2012; Galazoulas, Tzimou, Karamousalidis, & Mougios, 2012). For example, decreases in time trial performance of swimmers has been associated with extended recovery durations and correlated well with decreases in temperature (West, et al., 2012; Zochowski, Johnson, & Sleivert, 2007). Basketball players were found to decrease in jumping and sprinting ability following 20 minutes of passive recovery, factors which would inhibit performance in a competitive team sport (Galazoulas, Tzimou, Karamousalidis, &

Mougios, 2012). The effect of similar increases in recovery duration on football performance has to our knowledge not been investigated.

This study will investigate the effect of physical and perceptual effects of varied recovery durations on football players performing football specific activities. A comparison of the 20 minutes duration required for elite football matches will be made to shorter durations of 10 and 5 minutes, which are more commonly found at sub-elite levels and in current research (Zochowski, Johnson, & Sleivert, 2007; Fradkin, Zazryn, & Smoliga, 2010).

Chapter 2: Literature review

Pre-event exercise, also known as a warm up, is a well accepted method to improve overall performance in subsequent athletic competition (Fradkin, Zazryn, & Smoliga, 2010; Bishop, 2003b). A "warm up" (WU) is typically a short preparatory activity which is performed prior to exercise in many sporting environments involving both elite athletes and novices alike (Bishop, 2003a). As an accepted tool for improving athletic performance, WU have been regularly modified and altered by coaches and athletes throughout history in search of the winning formula (Volianitis, Koutedakis, & Carson, 2001). Despite the regular application of WU prior to training and competition in a variety of sporting codes, the science to explain and validate the practice is still relatively limited (Brown, Hughes, & Tong, 2008).

The influence a WU will have on subsequent performance will be dictated by the intensity, duration, protocol undertaken and the length of recovery time between end of the WU and the commencement of athletic competition (Mujika, de Txabarri, Maldonado-Martín, & Pyne, 2012; Holt & Lambourne, 2008; Faigenbaum, McFarland, Kelly, Ratamess, Kang, & Hoffman, 2010). To date, research has largely focussed on the characteristics of intensity, duration and protocol with less literature been applied to recovery time. The improvement in athletic performance has been attributed to increases in both core and muscle temperature (Bishop, 2003b), metabolic changes (Brunner-Ziegler, Strasser, & Haber, 2010), psychological aspects (Malareki, 1954) and changes to how muscle responds to stimulation such as post activation potentiation (PAP) (Chiu, Fry, Weiss, Schilling, Brown, & Smith, 2003). Injury prevention has also been an important factor in the development of WU protocols; however this is largely beyond the scope of this paper (for further details see Woods, Bishop, & Jones, 2007).

2.1 Active and passive warm up

Active and passive WU's are most commonly applied prior to athletic training and competition with the aim being to improve performance and decrease injury risk (Fradkin, Gabbe, & Cameron, 2006). An active WU involves the commonly applied method of performing a shortened sample of the activity about to be performed (Dadebo, White, & George, 2004). This is typically undertaken by performing low, moderate and high intensity exercise (i.e. jogging, running and sprinting) followed by sport specific exercises (i.e. passing or kicking a ball) (Soligard, et al., 2008). A large portion of performance benefits associated with an active WU are related to muscle and core temperature increases (Bishop, 2003b). However unlike passive WU, additional physiological modifications transpire (Ingjer & Strømme, 1979), including: reducing stiffness of muscles and joints, increasing the speed of nerve conduction and improving the force and velocity of power able to be produced based on force-velocity relationships (Binkhorst, Hoofd, & Vissers, 1977; Davies & Young, 1983).

Conversely, a passive WU refers to the practice of raising the body's core or muscle temperature by an external means such as hot body baths, heating pads or heat massage rubs. These methods serve to raise the temperature to similar levels as exercise without the loss of energy levels associated with exercise (Gray & Nimmo, 2001). The most common form of heat application is via the use of heated water baths prior to exercising (Brunner-Ziegler, Strasser, & Haber, 2010); allowing the entire body to be immersed thus ensuring an even distribution of heat. Other methods which have been used include saunas (Cooper, Martin, & Riben, 1976), diathermy (Draper, Knight, Fujiwara, & Castel, 1999) and heating pads (O'Brien, Payne, Gastin, & Burge, 1997).

2.2 Physiological advantages of increased temperature due to Warm Up

2.2.1 Force/velocity

Many of the improvements found following WU are related to an increased muscle temperature (Shellock & Prentice, 1985; Asmussen & Boje, 1945; Bishop, 2003a). One area of improvement is seen by the force-velocity curve which shifts to the right (Bergh & Ekblom, 1979). As demonstrated in Figure 2.1 (De Ruiter & De Haan, 2000), at a given force (i.e. 40, 50, 60%) the increased velocity of movement catalysed by a greater muscle temperature, leads to a greater power output profile. This thermal influence is greatest in those muscles which are predominantly fast twitch rather than slow twitch (Bennett, 1984). As fast twitch fibres are more efficient at higher contraction velocities than their slow twitch counterparts, the temperature mediated increase in velocity results in a larger power output response (Bell & Ferguson, 2009).

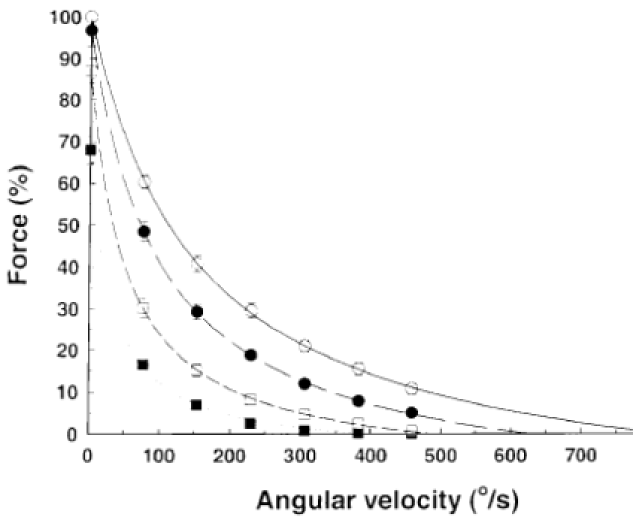

Figure 2.1: Force velocity curve showing the effect of temperature. Temperatures range from 22.2°C (Black box) on the left to 37.1°C (Clear circle) on the right. De Ruiter, C. J., & De Haan, A. (2000). Temperature effect on the force/velocity relationship of the fresh and fatigued human adductor pollicis muscle. *European Journal of Physiology* , 440(1): 166

As temperature increases, there is also an increase in the maximal velocity at which contractions can occur (Bottinelli, Canepari, Pellegrino, & Reggiani, 1996); however it should be noted there is no change in the isometric torque able to be created (Binkhorst, Hoofd, & Vissers, 1977). This effect was revealed using water baths to alter muscle temperature before stimulating the muscle (Clarke, Hellon, & Lind, 1958). Higher temperatures resulted in a reduced time to reach peak tension while cooler temperatures delayed this response (Petrofsky & Laymon, 2005). However previous research has been limited due to the use of isolated muscle fibres or inclusion of unrealistic physiological temperatures. These studies, while providing good supporting data, must be considered to contain limitations (Davies & Young, 1983; Bishop, 2003a). More precise methods of heating and measurement such as thermistors have allowed investigators to explore the practical implications of how temperature may affect the force production of skeletal muscle (Brajkovic & Ducharme, 2005).

Similar results have been observed when comparing in vivo testing to isolated fibres. An enhancement in muscle force and power was determined during cycling exercise and this equated to approximately 4% per 1˚C temperature increment (Sargeant, 1987). Interestingly, even low levels of cooling were sufficient to produce opposing results and decrease muscle performance (Oksa, Rintamäki, & Rissanen, 1997). By comparing cycling cadence it was demonstrated that increasing the velocity of contractions through higher a cadence, allows temperature to have a more pronounced effect on power output (Sargeant, 1987). This result would suggest that increasing temperature through either a passive or active WU is likely to have a larger influence on exercise modalities that involve high contraction frequency (Volianitis, Koutedakis, & Carson, 2001).

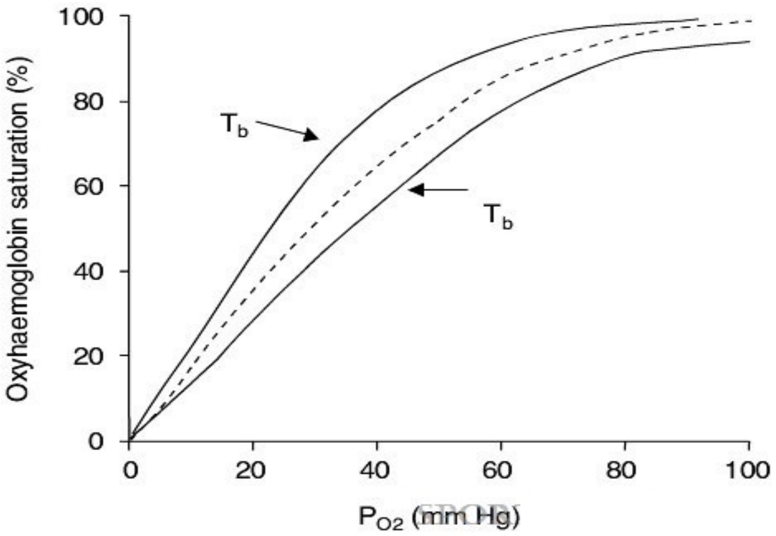

Figure 2.2: Effect of increasing or decreasing temperature on the oxyhaemoglobin dissociation curve. Tb on the right denotes an increased blood temperature while Tb on the left shows a lowered blood temperature. PO_2 stands for the partial pressure of oxygen. Bishop, D. (2003a). Warm up 1. Potential mechanism and the effects of passive warm up on exercise performance. *Sports Medicine* , 33 (6): 442.

2.2.2 Vasodilation and dissociation

Muscle performance also responds to increased temperature through vasodilation of blood vessels and shifts in the oxyhaemoglobin dissociation curve (Figure 2.2). This occurs though neural feedback loops in response to a heat stimulus such as exercise, heat rubs, saunas or hot water baths (Barcroft & Edholm, 1943). The body attempts to remove this extra heat by increasing blood flow to exterior vessels (Charkoudian, 2003). Increased levels of oxygen are rapidly supplied to the working muscle, with the end result being increased levels of ATPase activity (Brunner-Ziegler, Strasser, & Haber, 2010). Vasodilation of blood vessels increases the amount of blood available to the muscles due to elevated contact between the blood vessels and the muscle cells (Barcroft & Edholm, 1943; Delp & Laughlin, 1998). In addition to the heat induced vasodilation increasing blood supply, more oxygen can be transferred into the muscle cells due to an increased rate of dissociation from haemoglobin molecules (Barcroft & King, 1909; Koppo & Bouckaert, 2000). This is evident by a rightward shift in the oxyhaemoglobin dissociation curve, meaning that at a given partial pressure, more oxygen is available (and at a faster rate) to pass into the muscle cells. The effect of vasodilation and dissociation curve changes only become relevant if the oxygen supply to the muscle is shown to be a limiting factor in oxygen consumption ($\dot{V}O_2$) kinetics; however this appears to not be the case for healthy people below $\dot{V}O_2$ max (Bishop, 2003a). Due to a varying intensities of a football match, stages of a match may involve oxygen supply being the limiting factor. This does not discount any benefit produced by this method, as limitations to $\dot{V}O_2$ kinetics is still a hotly contested issue (Hajoglou, Foster, De Koning, Lucia, Kernozek, & Porcari, 2005; Poole, Barstow, McDonough, & Jones, 2008). Nevertheless, it has been suggested that increasing oxygen delivery is unlikely to be a significant determinant in performance, at least at lower levels of intensity (Poole, Barstow, McDonough, & Jones, 2008).

2.2.3 Nerve conduction

A WU is able to increase the conduction velocity of nerve signals sent to the muscles fibres thus allowing faster contractions and movement. This must be differentiated from the conduction velocity within a muscle fibre which occurs through different mechanisms (Pearce, Rowe, & Whyte, 2012). Important tools for these neural studies include Electromyography (EMG) (Farina, Merletti, & Enoka, 2004), which measures the electrical activity within a muscle and transcranial magnetic stimulation (TMS) which measures the time from stimulation to response (Hallett, 2000). Conduction velocities are heavily dependent on temperature and can vary by as much as 5% for every 1 ˚C change in temperature (Waxman, 1980). This increased speed of signals arriving at the muscles could be particularly important for tasks which require quick reactions as many team sports at the top levels necessitate (Bishop, 2003a). By increasing the speed of signals supplying the muscle, contraction takes place faster (Skof & Strojnik, 2007). As shown by the previously mentioned force velocity relationship, a faster muscle contraction will mean the power of each contraction becomes larger (Stewart, Macaluso, & De Vito, 2003). However, isolating this benefit to show that it is a direct resultant of a temperature increase alone has been difficult and requires further research.

2.2.4 Muscle and joint Stiffness

Another consequence of increasing temperature through WU is decreasing the stiffness felt in both muscles and joints (Girard, Carbonnel, Candau, & Millet, 2009). Possible mechanisms which would explain this effect include the breaking of actin-myosin bonds and decreased viscous resistance in both muscles and joints (Jones, Koppo, & Burnley, 2003). When Hill (1968) first proposed the sliding filament model of muscle contraction, he noted that when inactivated a muscle would form resting cross bridges between actin and myosin, providing tension to a muscle. Stiffness is difficult to quantify and as such the research is fairly subjective, however, it appears that after only a few seconds of inactivity, bonds begin to reform and stiffness around joints is increased (Lakie, Walsh, & Wright, 1984). Lakie and colleagues were able to decrease the resistance by contracting the muscles around a joint which was then maintained for as long as movement continued. This movement when used in combination with a stretching protocol enables maximal decreases in muscle stiffness (McNair & Stanley, 1996). A WU may work to break up the actin-myosin bonds which produced stiffness in a passive muscle fibre by moving a muscle through its range of motions, although as soon as activity ceases these bonds will begin to form again and negate any prior benefit (Lakie, Walsh, & Wright, 1984). Even low amounts of warming have been reported to decrease resistance of joints and muscles, and thus allow easier movement (Bishop, 2003a). It should be noted that this effect is likely to be small and how it responds to a period of inactivity is as yet unknown.

2.3 Post activation potentiation

A relatively new mechanism which explains improvements following WU is the process of post activation potentiation (PAP). This theory revolves around the principle that the contractile history of a muscle fibre affects how it will react during subsequent contractions. This is applicable for both voluntary muscle stimulation and electrical stimulation (Hodgson, Docherty, & Robbins, 2005). A common example of this is fatiguing muscle, where continuous contractions by a muscle will result in only being able to produce a lower amount of force. When PAP occurs however, a contrasting response is seen and prior maximal contractions are able to elicit a larger contraction response from the muscles (Tillin & Bishop, 2009). The conundrum for gaining benefit from PAP, is finding the balance between potentiating the muscle through prior stimulation while avoiding fatiguing the muscle through too much stimulation (Hamada, Sale, MacDougall, & Tarnopolsky, 2003).

The exact mechanism by which this is accomplished is as yet not fully understood but several theories have been suggested to explain the phenomenon (Sale, 2002). The first method is through phosphorylation of myosin regulatory light chains (RLC) which are located near the myosin heads (Baudry & Duchateau, 2007). When a contraction takes place, Ca^{2+} is released from the sarcoplasmic reticulum which activates enzymes and encourages phosphorylation of the RLCs (Stuart, Lingley, Grange, & Houston, 1988). Subsequent contractions have increased force potential due to changes in the RLC conformation and increased sensitivity to calcium. Increased Ca^{2+} sensitivity means the biggest advantages are seen when levels of calcium in the muscle cell are scarce and/or when contraction frequency is low (Sale, 2002). Fibre type may also have an influence with fast twitch type II muscle fibres being influenced more by PAP because they are able to be phosphorylated to a greater extent following a large contraction than slow twitch type I fibres (Hamada, Sale, MacDougall, & Tarnopolsky, 2000).

The H-reflex has also been suggested to be an important mechanism through which PAP enhances muscle contraction (Hodgson, Docherty, & Robbins, 2005). It is suggested that a repeated firing of action potentials will speed up the transmission of signals across synaptic junctions in the spinal cord when they are next called into action (Tillin & Bishop, 2009). The result of this alteration is increased efficiency and rate of nerve impulses arriving at the muscle. The H-reflex is negatively affected immediately following a large contraction but following a few minutes of recovery it becomes larger than its initial value and may contribute to the PAP phenomenon (Gullich & Schmidtbleicher, 1996); this effect has been shown to last for up to 16 minutes. The amount of time required to recover has not been agreed upon, and this has contributed to confusion with practical application of PAP (Gossen & Sale, 2000). However, it has been suggested that approximately 5 to 10 minutes is likely to allow potentiation to occur (Kilduff, Owen, Bevan, Bennett, Kingsley, & Cunningham, 2008).

As PAP affects fast twitch fibres more than slow twitch, power and explosive activities would expect to gain greatest benefits. However with increased Ca^{2+} sensitivity being a product of PAP, other activities with lower Ca^{2+} may be influenced to a greater extent. During intense exercise activities such as sprinting, the muscle cell is saturated with Ca^{2+} due to the high frequency of contractions thus nullifying any advantage of increased Ca^{2+} sensitivity (Hamada, Sale, MacDougall, & Tarnopolsky, 2000). However when competing or training in endurance events and during low intensity stages of football matches, the contraction frequency is much lower and sensitivity to Ca^{2+} becomes advantageous (Sale, 2004). Due to the size principle, if a higher force is being produced through a given stimulus, smaller more efficient muscles can be used which saves the larger more powerful fibres for when increased intensity is required or fatigue kicks in (Sale, 2002). As athletes participating in events such as sprinting or throwing competition have this saturation of Ca^{2+} in the muscle cell, they are unable to increase their maximal force through PAP. Crucially however, it allows them to increase their rate of force development which in practical terms increases the amount of power they can exhibit (Stuart, Lingley, Grange, & Houston, 1988). As the weights they are moving, whether it be body weight, ball or javelin, have a mass smaller than their maximal force, the speed at which they are able to reach the required force is the important issue for improving performance.

2.4 Metabolic effects

Metabolic processes are also able to benefit from increased muscle temperature which is induced following a WU protocol (Wittekind & Beneke, 2011). For example, an active WU may blunt the blood lactate (BLa) response during high intensity exercise (Martin, Robinson, Wiegman, & Aulick, 1975). This could be of particular benefit to the sport of football which requires repeated sprints as well as large amounts of low intensity running (Reilly, 1997). Blunted BLa responses following an active WU are possibly due to increased clearance rates during short rest periods (Gladden, 2000). Alternatively it could be due to beginning exercise with an increased volume of acetyl groups available (Gray, Devito, & Nimmo, 2002). This provides an interesting avenue for future research, however it should be noted that no performance improvement was found in this study despite various WU protocols. As these findings conflict with the general perception of improved performance following an active WU, flaws in the WU protocol may have contributed to these equivocal results.

Increasing muscle temperature, through passive methods alone is able to increase glycogenesis, high energy phosphate degradation and anaerobic glycolysis which means that carbohydrate is being used more predominantly as the fuel for exercise (Febbraio, Carey, Snow, Stathis, & Hargreaves, 1996). The exact mechanisms by which this occurs is still poorly understood but could be related to enzyme activation, increased ATP turn over during exercise or altering proportions of aerobic/anaerobic energy systems to fuel production. However, a study which controlled for muscle temperature by passively warming the muscle to the same levels achieved during active WU showed that muscle temperature is not the sole determinant of metabolic changes (Gray & Nimmo, 2001).

2.5 Oxygen consumption

A pertinent characteristic of utilising active WU's is the change to the energy system which is utilised at the start of competition. Athlete $\dot{V}O_2$ levels will be elevated following an active warm up and, provided a suitable recovery period is selected, will still be increased at the beginning of competition (Gutin, Stewart, Lewis, & Kruper, 1973; Jones, Koppo, & Burnley, 2003). During intermediate to endurance events this allows the primary system fuelling exercise to be aerobic rather than anaerobic (McCutcheon, Geor, & Hinchcliff, 1999). This saves anaerobic capacity for use at later stages in exercise when an increase in effort or speed is required. This provides an explanation for improved endurance following WU and has also been shown to occur in anaerobic activities lasting as briefly as 30 seconds, though an influence for shorter durations is unlikely (Guidetti, Emerenziani, Gallotta, & Baldari, 2007). The disadvantage of this mechanism is that full recovery may not have taken place by the time $\dot{V}O_2$ returns to resting levels, meaning that athletes run the risk of starting exercise in a fatigued state (Bishop, 2003b). This is an area where specific management of players should be applied by coaches to optimise WU intensity and duration, so that a positive balance between increased $\dot{V}O_2$ and fatigue is attained.

2.6 Effect of WU on mental preparation

An important aspect of WU for any athlete and particularly those competing in team sports is the psychological preparation for the match approaching (Pedersen, 2000). Interestingly hypnotising subjects into forgetting that they had performed a WU resulted in no performance increase (Massey, Johnson, & Kramer, 1961). This lack of improvement when mental preparation is removed would suggest possible mental benefits to WU, although protocol flaws in the study's WU raise validity questions. Visualisation of successful competition may be performed during WU and this had been shown to a common trait of high performing Olympic athletes (Ungerleider & Golding, 1991).

Perceptual measures are used to gain valuable insights into the psychological cost of exercise and are used in research to assess influence of interventions (Coquart, Legrand, Robin, Duhamel, Matran, & Garcin, 2009; Ali, Caine, & Snow, 2007). The felt arousal scale (FAS) is a common perceptual marker which indicates the mental activation of an athlete (Svebak & Murgatroyd, 1985). There is good validation evidence for this marker and as such it has been used in a variety of exercise research (Ekkekakis, 2003; Backhouse, Ali, Biddle, & Williams, 2007; Bellezza, Hall, Miller, & Bixby, 2009).

Another often used perceptual marker is the feeling scale (FS) which asked subjects to assume a squatting position before reporting their feelings on a scale ranging from very good to very bad (Hardy & Rejeski, 1989). The investigators Hardy & Rejeski (1989) reported good feelings at the beginning of exercise and this trended towards feeling bad by the end of exhaustive exercise and was reasonably similar to physiological measures. The final indicator often used to gauge a subject's psychological state is the rating of perceived exertion (RPE) scale which requires subjects to describe how hard they believe they are working (Borg, 1998). The scale ranges from 6-20 and was constructed with the intention of increasing linearly with exercise intensity; it has become very popular and is used by many areas of research (Yamashita, Iwai, Akimoto, Sugawara, & Kono, 2006; Lagally, et al., 2002). Due to easy implementation, the RPE also used as a training tool for sports teams to ensure that appropriate levels of intensity are allocated during exercise sessions (Impellizzeri, Rampinini, Coutts, Sassi, & Marcora, 2004). While not being a definitive measure of mental state before and during exercise, these scales provide an indication of the psychological condition of subjects and allow comparison of different experimental situations.

2.7 Performance improvements following warm wp

Contrasting results have been reported for the effect of an active WU on subsequent performance, with some reporting improvement (Hajoglou, Foster, De Koning, Lucia, Kernozek, & Porcari, 2005; Cè, Margonato, Casasco, & Veicsteinas, 2008) and others no differences when compared to no WU at all (Wittekind & Beneke, 2009; Binnie, Landers, & Peeling, 2012). There are even findings, although limited, which suggest an active WU can have a negative influence on the subsequent performance of the subjects (Gregson, Batterham, Drust, & Cable, 2002). The WU protocol used in this study required participants to run at 70% of their $\dot{V}O_2$ max until a rectal temperature reached 38°C. This WU may have caused fatigue and thermal stress thus leading to a negative WU influence.

There are several reasons for such contrasting results, large variation of testing modalities amongst studies makes comparison difficult; the variety of testing has included running (Bradleya, Sheldona, Woosterb, Olsenc, Boanasb, & Krustrupd, 2009), swimming (Zochowski, Johnson, & Sleivert, 2007), cycling (Gray, Devito, & Nimmo, 2002) and specific power activities (Church, Wiggins, Moode, & Crist, 2001). Other causes for these results may be due to variation in the intensity, atmospheric conditions and duration of the WU as these variables affect a participant's level of oxygen consumption and the thermo-strain their bodies are under (Bishop & Maxwell, 2009; Mujika, de Txabarri, Maldonado-Martín, & Pyne, 2012). These variations in protocol must be considered when deciding on the WU effect, analysis of studies currently published suggest that the majority of cases (79%) support an improvement in performance following an active WU (Fradkin, Zazryn, & Smoliga, 2010).

Passive WU has produced conflicting evidence for improving performance with the main determinant of results being the subsequent performance intensity. During longer duration exercise, thermoregulation can become a large inhibitor of performance; this is especially relevant in hot environments (Kozlowski, Brzezinska, Kruk, Kaciuba-Uscilko, Greenleaf, & Nazar, 1985). Research reflects this by suggesting increased muscle temperature has a very limited or possibly negative influence on endurance exercise (Gregson, Drust, & Batterham, 2002). During short, intense exercise, excessive heat accumulation is unlikely to limit performance and more favourable results have been associated with passive heating (Knight, Rutledge, Cox, Acosta, & Hall, 2001). For both vertical jump and intermittent sprinting protocols following a heated water bath, improvements in maximal height and speed were seen when compared to no WU (Davies & Young, 1983; Brown, Hughes, & Tong, 2008). However in hot conditions, a passive WU has been shown not to be as effective as an active WU (O'Brien, Payne, Gastin, & Burge, 1997). Just how long passive WU improvements can be maintained before the prior heat begins to have a limiting effect is as yet unknown.

2.8 Stretching

Another pre-competition tradition practiced by the majority of athletes is the stretching of major muscle groups. While this may aid in subsequent performance, usually the primary objective is prevention of injury (Witvrouw, Mahieu, Danneels, & McNair, 2004). Static and dynamic stretching are the two primary classifications. During static stretching the athlete adopts a position which will lengthen the muscle of interest and maintains that position for at least 15 seconds (Roberts & Wilson, 1999). Dynamic stretching will often use the same position but involves movement which stretches a muscle through its range of motion; this is usually performed for around 45 seconds (Little & Williams, 2006). The stretching of muscles, be it dynamic or static, aims to reduce injury prevalence by increasing the muscle length. Therefore during exercise when under an increased load, the muscle does not stretch to the point where muscle tears occur (Park & Chou, 2006). Ensuring that the muscle tendon unit is compliant enough to absorb repeated landings and the elastic energy this produces is crucial for avoiding injury (Witvrouw, Mahieu, Danneels, & McNair, 2004). This is particularly relevant for sports with high rates of landing at speed, such as football or rugby but may be less important for sports such as cycling which does not have the same impacts regularly involved (Fuller, et al., 2006). Further research is required to determine the mechanisms and influence of static versus dynamic stretching however, while there is evidence to suggest that stretching before competition will lower the incidence of muscle strains (McHugh & Cosgrave, 2010). The effect appears to be small and several meta-analyses performed have shown little benefit for static stretching decreasing injury risk or improving performance (Thacker, Gilchrist, Stroup, & Kimsey, 2004; Small, McNaughton, & Matthews, 2008).

While some beneficial results have been shown for static stretching (de Weijer, Gorniak, & Shamus, 2003), dynamic stretching appears to produce superior performance (Fletcher & Jones, 2004; Little & Williams, 2006; Holt & Lambourne, 2008). A short period of dynamic stretching has been shown to increase muscle activation rates, whilst also maintaining maximal power production (Herda, Cramer, Ryan, McHugh, & Stout, 2008; Manoel, Harris-Love, Danoff, & Miller, 2008). Research also indicates that including dynamic stretching as part of the WU protocol will positively influence performance of both power and agility activities (McMillian, Moore, Hatler, & Taylor, 2006). Static stretching has been linked to a decrease in subsequent sprinting performance and limited influence on injury risk, therefore dynamic stretching is the more advisable method prior to competitive exercise (Fletcher & Anness, 2007; Little & Williams, 2006).

2.9 Application of WU protocol in elite football

Football in the world's largest participation sport and places a variety of physical demands on players including repeated sprinting, jumping, physical contact and high volumes of running over the course of a 90 minute game (Bangsbo, Mohr, & Krustrup, 2006). The global governing body of football (Fédération Internationale de Football Association, FIFA), has introduced a program called the FIFA 11+ (Bizzini, Junge, & Dvorak, 2008) which they advise being carried out several times a week prior to training or games. The program is split into 3 parts: slow jogging, a series of core and leg exercises and a final section incorporating faster running and change of directions, which takes approximately 20 minutes. The program has been trialed on young female players and found it effective at lowering over use and general injuries when analyzed over the course of a season (Soligard, et al., 2008). Implementation of the program over several months has produced improvements in muscle strength surrounding the knee (Brito, et al., 2010), potentially lowering knee injury rates. When the program was utilized by amateur Italian males, the level of football ability processed appeared to be the only factor which influenced injury rates, while no measure of performance influence was made (Gatterer, Ruedl, Faulhaber, Regele, & Burtscher, 2012).

Due to the global nature of football, much interest is placed on major competitions and incredible amounts of money are spent on televising matches around the world (Horne & Manzenreiter, 2004; Maenning & Plessis, 2007). This can have a large influence on the conditions in which players are exposed to, significantly altering the WU protocols that can be implemented before these matches. As shown in Figure 2.3, very tight time allowances are allocated for players' WU on the field of play (Blatter & Linsi, 2003).

Countdown activity	**Time until kick off**
Arrival of teams	-90 minutes
Collection of team line ups	-75 minutes
Goalkeeper can begin warm up	-50 minutes
Outfield players begin warm up	-45 minutes
All players must leave pitch	-20 minutes
Players in tunnel ready to enter pitch	-9 minutes
Start of pre-match ceremony	-7 minutes

Figure 2.3: Example of match day schedule for teams competing at elite FIFA sanctioned tournaments. Adapted from guidelines for FIFA match officials (Blatter & Linsi, 2003).

Goal keepers are permitted to WU for a maximum of 30 minutes while outfield players are limited to just 25 minutes before they must head back into changing rooms to finish preparations. Of particular interest is that players are required to be off the field 20 minutes prior to the match commencing, with approximately half of the remaining time before kickoff spent in ceremonial activities. This is a longer period than WU effects are expected to be applicable however the influence this may have on performance once matches begin is as yet not fully understood (Journeay, Reardon, Martin, & Kenny, 2004; Saltin, Gagge, & Stolwijk, 1968; Bishop, 2003b). The difficult nature of quantifying football performance is perhaps a contributing factor for why more research has not been applied in this area.

2.10 Warm up intensity and duration

If the WU used in the study procedure is too short or the recovery duration too long to result in oxygen consumption being higher than resting, the previously mentioned aerobic utilisation benefits are unable to take place. The routine must also be sufficient to cause an increase in muscle and core temperature. Conversely if the WU protocol is too long, too intense or not enough recovery time is permitted then the athlete may start competition in a fatigued state (Mujika, de Txabarri, Maldonado-Martín, & Pyne, 2012). The fatigue factor of a WU is highlighted by studies involving both trained and untrained athletes where the procedure was not manipulated to accommodate the varying levels of fitness (Bishop, 2003b). The untrained group suffers fatigue from the WU which is too strenuous for their fitness level and subsequent performance is inhibited. The trained group suffer less fatigue following WU and their performance is improved. (Andzel, 1978; Andzel & Busuttil, 1982). This becomes important in a team environment which may have athletes of varying level of fitness. Accordingly a uniform WU protocol may not be appropriate for all individuals. This was recently examined by Mandenguea et al. (2009). In their study, the authors compared performance following a self selected WU intensity, to that 10% above or 10% below. Interestingly the subjects were successful in selecting a WU level for themselves, as the self selected protocol produced the best results during subsequent performance testing (Mandenguea, Miladi, Bishop, Temfemoa, Cisse, & Ahmaidi, 2009).

Care must also be taken when competing in hot conditions so that temperature increases caused by WU do not have a limiting effect on performance (González-Alonso, Crandall, & Johnson, 2008). Beyond a set point of approximately 40°C, exercise will be limited to maintain homeostasis and deal with increased skin blood flow, dehydration and hyperthermia (Schlader, Stannard, & Mündel, 2011). With this set point in mind, if an athlete begins competition at an elevated temperature they are likely to reach the set point earlier and suffer from fatigue; this is particularly evident during endurance events in the heat (Bishop & Maxwell, 2009). Accordingly, when competing in hot conditions athletes attempt to minimise thermo stress by cooling the body down by external means, such as ice vests or cooling baths prior to competition (Arngrïmsson, Petitt, Stueck, Jorgensen, & Cureton, 2004).

2.11 LIST

Football is a sport which is made up of repeated bouts of sprinting in combination with walking, jogging and fast running just short of full speed (Reilly, 1997). Recreating the demands of a football game in a laboratory environment is a very difficult exercise due to the unpredictability of movements and varied physical demands. For this reason, it is unrealistic to use a simple straight line running protocol as a platform for measuring the match fitness of a player. Accordingly, following some preliminary research trials (Nicholas, Williams, Phillips, Lakomy, & Nowitz, 1995), the Loughborough intermittent shuttle test (LIST) (Nicholas, Nuttal, & Williams, 2000) was designed to accurately simulate the running demands of a player during the course of a football game. Totaling approximately 90 minutes of exercise, the test was split into two parts with the first incorporating 5 blocks of 15 minutes. Within each 15 minute block subjects performed a combination of walking, running and sprinting, with each block being separated by 3 minutes of rest. Part 1 of the LIST consisted of 5 blocks of this protocol before a final 3 minute recovery period. This was followed by part two, which was made up of an open ended exhaustion test where subjects ran at variable speeds until they were unable to continue. Part 2 was designed to exhaust participants after approximately 10-15 minutes. This test requires subjects to have completed a recent $\dot{V}O_2$ max test in order for time values to be calculated for 55% and 95% of $\dot{V}O_2$max running speeds. It is also possible for alterations to be made to the LIST design so that football skills can be incorporated and assessed (Foskett, Ali, & Gant, 2009).

2.11.1 Running distance

This test was created following close analysis of football games, so that factors such as running distance and also the ratio of different running speeds could be replicated by LIST (Nicholas, Nuttal, & Williams, 2000). The total running distance from the LIST (~ 12.4 km), although dependent upon position, is similar to that observed during match analysis of top football players (10-13km) (Nicholas, Nuttal, & Williams, 2000; Bangsbo, Mohr, & Krustrup, 2006). The distance a player will run within a match is influenced heavily by their personal talent and at what level they are playing, as well as the style in which their team has been instructed to play with (Bangsbo, Mohr, & Krustrup, 2006). This was highlighted by elite English players running on average 1.5 km further than their South American counterparts (Reilly & Gilbourne, 2003). Although the distance performed in the LIST is currently applicable to match situations, this may need to be adapted in the future as elite players are now running further than they were in previous generations (Strudwick & Reilly, 2001); a trend which is likely to continue.

2.11.2 Turns

Based on a player performing the LIST with a $\dot{V}O_2$ max of 60 (ml·kg^{-1}·min^{-1}) who lasts for 10 minutes on the exhaustion section, 731 turns will be completed, similar to the 727 ± 203 turns observed with English premiership players during a competitive match (Bloomfield, Polman, & O'Donoghue, 2007). The variability demonstrated by Bloomfield and colleagues may be accounted for by the influence of player position, with defender making more turns in a game than both attackers and midfield players (822 ± 175 vs. 748 ± 173 and 608 ± 207 respectively). The disadvantage of turning in the LIST is that the varied type of turns performed in a match is only replicated by complete 180°C changes of direction (Salvo, Baron, Tschan, Calderon Montero, Bachl, & Pigozzi, 2007). These comparisons suggest that for both distance and amount of turns, the LIST is an acceptable simulation of a competitive football match which can be performed in a controlled environment (Magalhães, Rebelo, Oliveira, Silva, & Marques, 2010).

2.11.3 Sprints

The amount of sprints performed during a match is a crucial factor for creating an accurate football match simulation, due to the high amounts of energy taken to perform each effort. There are some issues with quantifying this factor from match analysis because of the hugely variable lengths and speeds performed by a player during a match; positional differences in sprint volumes are also clearly evident. Nicholas, et al (2000) reported that the amount of sprints during LIST (~55) was similar to that found in a normal football match. However more recent analysis suggests this may not be the case with high level players performing 35-39, which is significantly lower than the amount performed during LIST (Bradleya, Sheldona, Woosterb, Olsenc, Boanasb, & Krustrupd, 2009; Mohr, Krustrup, & Bangbo, 2003). While a research group analysing elite players from the Spanish league showed an even larger disagreement with only 17.3 sprints being performed in a game (Salvo, Baron, Tschan, Calderon Montero, Bachl, & Pigozzi, 2007). The LIST test uses a distance of 20 meters for each sprint which is appropriate with match analysis showing distances of 19.3 m ± 3.2 as an average high intensity run (Salvo, Baron, Tschan, Calderon Montero, Bachl, & Pigozzi, 2007). This data would suggest that the amount of sprinting in the LIST protocol is higher than that seen in proper matches and may be a limitation when considering this type of testing.

2.11.4 Time spent at different exercise intensities

Analysis of football matches is also able to show the amount of time that a player spends standing or recovering, walking and running at both low and high intensities. Encouragingly, in comparison to match analysis the LIST provides participants with a similar amount of time walking (48.1% cf. 41.8%, respectively) and running at low intensity (24.7% cf. 29.9%). However match play produces increased levels of high intensity running compared to the LIST (19.3.0% cf. 8.7%) (Nicholas, Nuttal, & Williams, 2000; Mohr, Krustrup, & Bangbo, 2003). The largest difference in ratio was found in standing time, (4.9% cf. 19.5%), and along with the splitting of a 15 minute break into 5 separate 3 minutes breaks, must be considered a limitation of the LIST. The main difference which can help to explain the difference in ratio results is the cut off points used to determine how a run was classified. To allow match analysis to work, strict speed boundaries have to be decided upon and within each category a range of running speeds may be performed. For example the following classifications are often used during match analysis standing (0 km·hr^{-1}), Walking (6 km·hr^{-1}), jogging (8 km·hr^{-1}), low speed running (12 km·hr^{-1}), moderate speed running (15 km·hr^{-1}), high speed running (18 km·hr^{-1}), sprinting (30 km·hr^{-1}) and sideways and backwards running (10 km·hr^{-1}) (Mohr, Krustrup, & Bangbo, 2003). This means that some of the runs may have been very close to crossing over between low and high intensity which may have altered the results were slightly different boundaries implemented. However during the LIST, the same speed was required for all time spent running in the different classifications. In addition the different speeds measured during a match analysis allow more classifications to be considered.

Making a final comparison between match play and the LIST protocol is difficult given the variety of research which uses different levels of players, countries, friendly vs. competitive games and classifications of running speeds. By using the same subjects to complete a match and LIST protocol within the space of 2 weeks, more direct comparisons can be made (Magalhães, Rebelo, Oliveira, Silva, & Marques, 2010). With the exception of heart rate which was higher following a match, LIST appears to be a suitable simulation of a football match which is able to be carried out in a more controlled environment.

2.12 Recovery duration following Warm Up

A crucial aspect of WU, which is often overlooked in terms of both research and practical application, is the amount of time permitted between completion of the WU and commencement of competition. As previously discussed following the WU a suitable amount of time is required to ensure fatigue is not a factor while conversely an excess of time will negate any benefits as physiological systems return to resting levels (Bishop, 2003b). Just which time period will elicit the optimal response is a question which research has overlooked to date, especially in relation to football players. The amount of recovery time that is currently used by most athletes around the world is highly variable and often dependent on the sports being played and the level of competition.

Different sports have similar issues with long periods between WU and performance and in particular swimming has an extended period of approximately 45 minutes; a reflection of most facilities not having a separate WU pool (Romney & Nethery, 1993; West, et al., 2012). This would be far longer than WU benefits would be expected to last for, especially in terms of elevated temperature and $\dot{V}O_2$ levels (Saltin, Gagge, & Stolwijk, 1968). This has been investigated using competitive swimmers who following an active WU recovered for either 45 or 10 minutes before a time trial was performed. As expected the 10 minute recovery produced a significantly better performance than did a 45 minute recovery, with the biggest differences coming in the final stages of the 200m time trial performed (Zochowski, Johnson, & Sleivert, 2007). Following the longer recovery duration, the athletes struggled to maintain their speed in the final 50 m while the shorter recovery allowed athletes to sustain performance until the end. Swimmers are called into competition protocols approximately 20 minutes before their race starts meaning the 10 minute recovery time used is impractical. To avoid this flaw, a similar study was recently performed comparing the 45 and 20 minute recovery durations (West, et al., 2012); again the shorter duration was found to benefit performance. While recovery duration has been investigated for swimming, basketball and baseball (Wilson, et al., 2012; Galazoulas, Tzimou, Karamousalidis, & Mougios, 2012; Zochowski, Johnson, & Sleivert, 2007), no current research exists for how variation of recovery duration may affect football performance

While research looking specifically at the amount of recovery time allowed following WU is very limited, it has been shown as a consequence of other research focuses. One such study investigated the power attributes of young athletes following different modes of stretching during a WU and reassessed the response every second minute for the 22 minutes following WU (Faigenbaum, McFarland, Kelly, Ratamess, Kang, & Hoffman, 2010). The athletes had increased vertical jump ability for the first 18 minutes following a dynamic WU protocol. Again the conversion of these results into the football player context is limited due to the exercise modality being tested, the young age group used and limited WU that was performed. However it does demonstrate that the elevated power output profile may be longer than the 10 minute time frame but decreased by 20 minutes post WU. Similar results were found when testing young football players immediately following WU and at 3 then 6 minutes. A dynamic WU with several resistance exercises was able to elicit a better jumping and sprinting performance (20 m) for the first 6 minutes of testing, however the main focus of the research was different forms of stretching (Needham, Morse, & Degens, 2009). While this study was very short in testing duration, it is perhaps more applicable to football recovery durations due to football players being used and because sprinting performance was measured. However WU protocols were short and quite unorthodox which decreases the legitimacy of these results.

The mechanisms that underline WU provide contrasting suggestions for optimal recovery duration. $\dot{V}O_2$ levels will return to resting physiological levels within approximately 5 minutes of recovery. Yet substrate levels, which are used to fuel mainly high intensity exercise and are partially used during an intense WU, require a minimum of 5 minutes to return to prior levels (Dawson, et al., 1997). Other sources have suggested that full replacement of all substrate stores could take up to 20 minutes (Harris, Edwards, Hultman, Nordesjö, Nylind, & Sahlin, 1976). The other crucial determinant of WU is muscle temperature, which is more long lasting, and depending on the external temperature conditions may stay elevated for 15-20 minutes. An optimal level that is able to incorporate these benefits has yet to be found for football players with only limited research being found in selected sports.

2.13 Conclusion and study rationale

WU is an important aspect of subsequent performance and has a multitude of physiological mechanisms. An active WU combined with dynamic stretching is most likely to elicit a superior subsequent performance (Bishop, 2003b; Fletcher & Anness, 2007). Increased temperature brought on by exercise is able to increase power production, speed up oxygen delivery, decrease stiffness in muscles and joints, whilst also speeding up the conduction of nervous activity to muscles (West, et al., 2012). In addition to temperature effects, changes take place in both metabolic and oxygen consumption processes, which given the right conditions can improve how an athlete competes. If strength based activity is included in the WU protocol, there is a prospective benefit from the PAP phenomenon although this is still poorly understood.

These mechanisms are all heavily influenced by the intensity, duration, environment conditions and amount of recovery permitted following a WU. A coach in order to suit the athletes and promote optimal performance may modify some of these factors. However in some sports, the amount of recovery time will be dictated by competition scheduling. This is an issue for football players with sanctioned events requiring players to finish their WU 20 minutes prior to match commencement; how this effects performance is currently unknown. The purpose of this study was to investigate how this extended recovery duration may impact of physical and perceptual levels of performance. To investigate this issue, the LIST test will be used to replicate the physical demands of a football match in a controlled environment following long (20 minutes), intermediate (10 minutes) and short (5 minutes) recovery durations.

2.14 Hypothesis

Based on the mechanisms previously discussed, it is hypothesized that recovery duration of longer than 5 minutes but less than 20 minutes is likely to elicit the greatest performance benefit for football players. This is because substrate levels are likely to be diminished after duration of 5 minutes while 20 minutes is long enough for temperature levels to return to resting levels thus limiting performance. Therefore a 10 minute recovery duration is predicted to provide optimal performance during the LIST protocol by extending the time to reach exhaustion and enhancing sprint performance throughout.

Chapter 3: Methods

3.1 Participants

Thirteen physically-active men (24.1 ± 3.9 y, 180.0 ± 5.6 cm, 76.2 ± 7.9 kg) volunteered to participate in the study[1]. In accordance with the ACSM (2010) risk stratification assessment (physical activity readiness questionnaire [PARQ]: Appendix A; coronary artery disease [CAD]: Appendix B, participants were healthy and asymptomatic of illness and injury.

All participants were recruited from the highest football competition in the lower North Island of NZ (men's central league), following permission from the respective club's chairperson to contact players. Prior-to and during study participation, each week players typically attended 2 to 3 team training sessions (~ 2 hrs per session), competed in a 90 minute football match at the weekend and undertook at least one gym session (resistance training). The recruited participants included four defenders, six midfielders and three forwards. All participants were informed of the demands of the study (Appendix C) and provided verbal and written consent (Appendix D). Research was conducted in accordance with the institutional human ethics committee (Appendix E).

[1] Twenty participants originally volunteered to participate in the study. However, seven subjects were unable to complete all experimental trials due to obtaining injuries during the football season. As such, these participants have been removed from all analyses.

3.2 Procedures

We used a within-subjects experimental design to assess the effect of recovery duration post WU on physiological, perceptual and performance markers of top regional Wellington football players. Each participant completed five assessment sessions; a graded exercise test (GXT) to maximal functional capacity, a baseline assessment for athletic performance, and three experimental trials. The order of each experimental trial was randomly assigned to participants.

The GXT was performed in the exercise physiology laboratories at Massey University. The GXT determined whether participants were of suitable aerobic fitness to participate in the experimental trials. Respiratory gas analysis (oxygen uptake [$\dot{V}O_2$], minute ventilation [$\dot{V}_E$], respiratory exchange ratio [RER]) and heart rate (HR) were continuously monitored. Perceived exertion, using the Borg 6-20 ratings of perceived exertion (RPE) scale (Borg, 1998) was assessed following the completion of each exercise stage. On-line respiratory gas analysis occurred using a breath-by-breath automatic gas exchange system (Sensormedics Corporation, Yorba Linda, CA, USA) following volume and gas calibration. Expired air was collected continuously using a facemask (Hans Rudolph, Inc., Shawnee, USA). Heart rate was monitored using a wireless chest strap telemetry system (Polar Electro T31, Kempele, Finland). All physiological markers (i.e. $\dot{V}O_2$, $\dot{V}_E$, HR), were hidden from the participant during the test.

Blood lactate (BLa) samples were taken from the subjects by way of a finger prick and processed using an Arkray lactate pro analyser (Akray, Minami-Ku, Kyoto, Japan). BLa samples were taken at rest, on completion of the GXT and following a five minute recovery (Tanner, Fuller, & Ross, 2010; Pyne, Boston, Martin, & Logan, 2000).

The baseline assessment for performance measures and the three experimental trials were completed in a gymnasium on the Massey University campus. The baseline assessment involved each participant completing a series of maximal sprints, agility tests and vertical jump (VJ) assessments. Sprint and agility times were assessed using infrared sportstec timing gates (Warriewood, NSW, Australia), while VJ was measured using a vertec (Swift performance equipment, Lismore, NSW, Australia). The experimental trials consisted of participants receiving three different recovery durations (5-, 10- & 20 minutes) following a moderate- to high-intensity WU. On completion of each respective recovery duration, participants completed the aforementioned performance assessments (sprint, agility, VJ) followed by the Loughborough intermittent shuttle test (LIST). There was a minimum 72 hour interim period between the GXT and baseline performance measures, while a 7 day recovery period was permitted between each experimental (LIST) protocol.

3.3 GXT to maximal functional capacity

The GXT to maximal functional capacity was performed on a treadmill (True Fitness Technology, Missouri, USA) in a thermo-neutral laboratory environment (22.4°C ± 1.7, 40.6% ± 6.4 and pressure of 1004.6 ± 8.1). Prior to the start of the test, participants completed a 5 minute WU period, incorporating a moderate-intensity run (~ 11 $km \cdot hr^{-1}$) and stretching exercises. The GXT was continuous and incremental, commencing at 11-13 $km \cdot hr^{-1}$ depending on the anticipated aerobic fitness of the participant, and increasing by 1 $km \cdot hr^{-1}$ every 3 minutes until test termination. The treadmill was set to 1 % throughout the duration of the test (Jones & Doust, 1996). Criteria for test termination included: a plateau in oxygen consumption of 2 mL·kg^{-1}·min^{-1} despite an increase in exercise intensity (running speed), a respiratory exchange ratio (RER) ≥ 1.15, the attainment of age-predicted maximal heart rate (Gellish, Goslin, Olson, McDonald, Russi, & Moudgil, 2007), or if the participant reported volitional exhaustion (Thompson, Gordon, & Pescatello, 2009). To take part in the experimental trials, participants' maximal oxygen uptake ($\dot{V}O_2max$) was required to be ≥ 50 mL·kg^{-1}·min^{-1}. The GXT to maximal functional capacity was used to calculate the exercise intensities (running speeds) used during the subsequent experimental trials.

3.4 Baseline performance measures

Baseline performance was assessed using a 15m sprint, agility and VJ test. Adequate recovery was provided in between each activity with a minimum of 2 minutes rest between tests to ensure there was no decline in performance (Spencer, Bishop, Dawson, & Goodman, 2005).

3.4.1 Sprint

Participants were instructed to perform a maximal straight line 15m sprint following a three second count down from the investigator. The starting point was determined as 1 m behind the first set of speed gates. The lights were activated when the subject broke the infrared beam at the start and again when passing through the timing gates situated at 15 m. Each subject performed three sprints with their best time being recorded.

3.4.2 Agility

Agility performance was determined using the 3-cone shuttle drill test (Figure 3.1), an agility test commonly used by the National Football League as a performance measure (McGee & Burket, 2003).

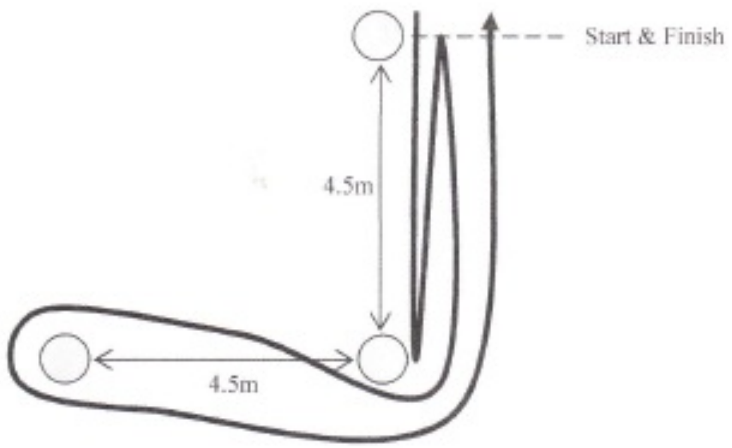

Figure 3.1: Schematic of agility test performed during baseline measures.

The athlete starts at cone 1. On his own volition, the athlete sprints as fast as possible and touches cone 2, which is 4.5m directly in front then immediately returns to cone 1. Without stopping, the athlete changes directions, corners cone 2, and sprints directly to cone 3, on the athlete's right-hand side. The athlete circles cone 3 to his left, then returns to the first cone by cornering cone 2 and sprinting at full speed past cone 1, which marks the finish line. Infra-red timing gates were positioned at cone one and provided times to the nearest one-hundredth of a second. Participants completed the test 4 times, alternating between running to the left and to the right upon reaching the second cone, and interspersed with a 2 min rest period between each attempt to ensure adequate recovery (Spencer, Bishop, Dawson, & Goodman, 2005).

Each subject started 1 m behind the start line to ensure that the timing gates were not prematurely set off.

3.4.3 Vertical Jump

Participants were required to perform 3 countermovement VJs. The test began with the participant standing erect; thereafter the participant volitionally performed a countermovement jump in which they were required to squat down to their optimal depth (approximately 90^{o} of hip & knee flexion) and then immediately jump vertical in order to achieve maximal height (Williams, Oliver, & Faulkner, 2011).

3.5 Experimental trials

3.5.1 Pre-measures

Participant's had a minimum one week recovery after their GXT to maximal functional capacity before commencing their first (of three) experimental trial. Participants' body weight and resting BLa and heart rate were measured at the start of each experimental trial prior to undertaking the WU. Participants completed each experimental trial at a similar time of day to control the variation in circadian rhythm (Drust, Waterhouse, Atkinson, Edwards, &

Reilly, 2005) and the environmental conditions (15.9 ± 2.5 °C, humidity 62.8 ± 10.6 % and 998.9 ± 6.5 mmHg).

3.5.2 Warm up

A standard 20-min WU was performed during each experimental trial. The WU included football specific movements such as passing a football, general WU activities incorporating jogging and stride outs and dynamic stretching such as leg swings. The WU commenced with low intensity activities and following stretching activities culminated with higher intensity and football specific exercises. Physiological (BLa, HR) and perceptive measures (Feeling scale [FS; Appendix F] (Hardy & Rejeski, 1989), Felt arousal scale [FAS; Appendix G] (Svebak & Murgatroyd, 1985)) were taken immediately following the WU. For further information concerning these measures, please see section 3.7.1. At completion of the WU, subjects were then required to rest for either 5-, 10- or 20-min (5_Rec, 10_Rec and 20_Rec). During this time participants were restricted to passive recovery (i.e., by sitting down) or low intensity locomotion (i.e., walking) in an effort to replicate pre-match changing room conditions. Identical physiological and perceptive measures to those reported above were noted following the recovery duration. Thereafter, participants' sprint, agility and vertical jump performance was re-assessed. The orders of these measures were kept consistent throughout testing, with vertical jump always being the final measure in an attempt to try and limit any influence of acute post activation potentiation (Gossen & Sale, 2000).

3.6 LIST

On completion of the performance measures, participants commenced the LIST (Nicholas, Nuttal, & Williams, 2000). The LIST test is a 90 minute intermittent sprinting protocol designed to replicate a football match (see section 2.11 for details regarding validity of match replication). The first 75 minutes of the LIST consists of 5 x 15 minutes blocks of exercise. Each 15-min block includes the following pattern of exercise:

· 3 x 20 m walk

· 1 x 20 m Sprint

· 4 s recovery

· 3 x 20 m jog at a running speed corresponding to 55 % of an individual's $\dot{V}O_2$ max

· 3 x 20 m run at a speed corresponding to 95 % of an individual's $\dot{V}O_2$ max

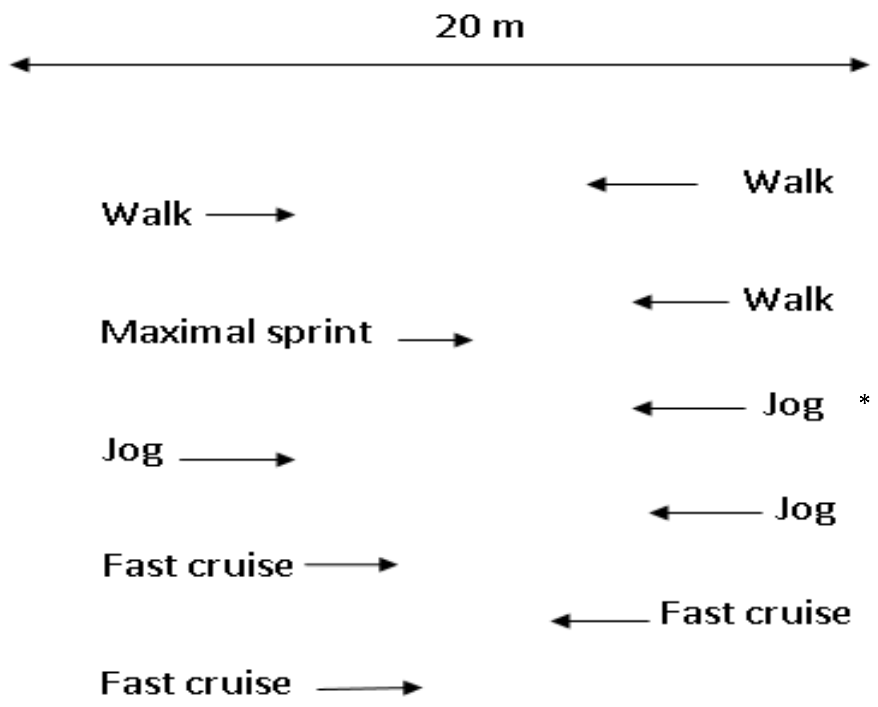

Figure 3.2: Schematic of running protocol during LIST. This cycle is repeated for the 15 minutes of each block in part 1 of LIST. Lengths were performed to a computerised beep programme with jog being 55% of $\dot{V}O_2$ max while fast cruise corresponded to 95% of $\dot{V}O_2$ max. The 4 second rest period following the maximal sprint is shown by *.

This pattern of exercise continues until 15-mins of exercise has been completed. The beep protocol for this test was made using specialized computer software. Dependent on each subject's $\dot{V}O_2$max, alterations were made to the amount of time subjects could take to complete each 20 m length. Participants had a 3-minute recovery period following completion of each 15-min block of exercise. During this interim period, participants reported their RPE, FS and FAS. On completion of the first, third and fifth block of exercise, BLa was also measured. Once the fifth block of exercise had been concluded, and following a further 3-min recovery, participants completed a time-to-exhaustion test. This test involved participants running the 20 m distance at alternative speeds corresponding to 55% and 95% of $\dot{V}O_2$ max. This process continues until the subject reaches exhaustion and is unable to finish the shuttle in the required time. Expected time for exhaustion testing is 10-15 minutes, taking the total exercise time of the LIST test to approximately 90 minutes (Nicholas, Nuttal, & Williams, 2000). Physiological and perceptive measures were collected on completion of the time-to-exhaustion test. Participants completed an identical test protocol during the remaining experimental trials, although an alternative recovery was implemented following the WU.

3.7 Measures of perception

3.7.1 FS and FAS

Feeling scales indicate the level of pleasure or displeasure on a scale ranging from -5 through to +5, with -5 equating to feeling very bad while +5 represented feeling very good (Appendix F). Participants were asked to go down into a squat (approximately 90^{o} of hip & knee flexion), and while in that position to identify on scale how they were feeling. Participants were also asked to rate their level of arousal using the 6 point FAS (Appendix G).

3.7.2 RPE

The Borg 6-20 ratings of perceived exertion (RPE) scale was used to quantify participants' subjection perception of exertion. Participants were perceptually anchored to the scale prior to each experimental trial (i.e. RPE 9, 13 and 20). Participants received standardized written and verbal instructions on how to identify and report their overall perception of exertion.

3.8 Heart rate

Heart rate (HR) levels were continuously recorded throughout the WU, recovery duration and LIST by way of Polar TEAM^2 system (POLAR, Oulu, Finland).

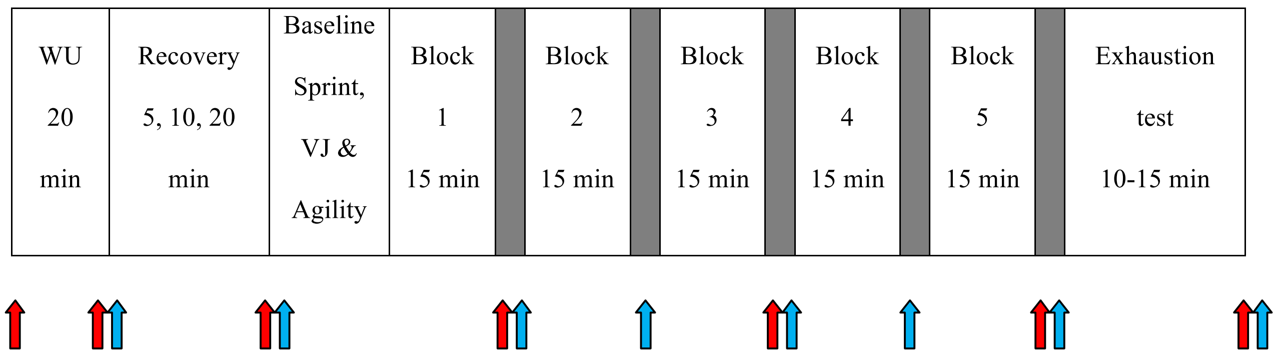

Figure 3.3: Schematic of experimental protocol. Red arrows indicate BLa sampling and blue arrows indicate collection of perceptual markers (RPE, FS and FAS). Shaded areas represent 3 minute rest periods.

3.9 Statistical analysis

A series of paired sample t-tests were used to compare the peak 15-m sprint, agility and vertical jump results following each recovery duration (5_Rec, 10_Rec & 20_Rec) with the initial baseline performance assessment. To reduce the risk of Type I error, a Bonferroni adjustment was used (0.017) (Bender & Lange, 2001). A series of one-way ANOVAs were used to compare the effect of recovery duration (5_Rec, 10_Rec and 20_Rec) on BLa, HR, FAS and FS at pre-WU, post-WU, pre-LIST and post-LIST.

Two factor repeated measures ANOVAs; Test (5_Rec, 10_Rec and 20_Rec) by Block (15, 30, 45, 60 & 75 min) were used to assess the effect of recovery duration on FAS, FS, RPE and HR. A similar analysis was used to compare BLa between tests, although this measure was only monitored at 15, 45 and 75 min during the LIST. Mauchly's test of sphericity was used to test assumptions of equality of variance. Where violations of sphericity were evident, the Greenhouse-Geisser Epsilon value was used. Where statistical differences were observed, post-hoc analysis was implemented to reduce the risk of type I error. Pairwise comparisons were used to locate Test main effect whilst repeated measures contrasts were used for Time main effects. Tukey's honestly significant difference (HSD) analysis was used to identify the location of any significant interactions (Gill, 1973). The HSD provides the minimum difference in means of two groups which must be exceeded for significance to be declared. All analyses were conducted on SPSS version 20. Statistical significance was set at $P = .05$ and adjusted accordingly.

Chapter 4: Results

4.1 GXT to maximal functional capacity

The mean (± SD) physiological responses from the GXT to maximal functional capacity are reported in Table 1.

Table 4.1: Physiological and physical data from GXT to maximal functional capacity. Data are reported as mean ± SD.

	Mean ± SD
VO_2max (L·min^{-1})	4.34 ± .70
VO_2max (mL·kg^{-1}·min^{-1})	56.8 ± 7.6
VE (L·min^{-1})	132.2 ± 15.5
RER	1.08 ± .06
HR max (b·min^{-1})	193 ± 14
BLa resting (mmol/L)	2.86 ± 1.60
BLa peak (mmol/L)	12.98 ± 4.60
BLa recovery (mmol/L)	8.85 ± 3.34
Peak speed (km·h^{-1})	16.0 ± .8
Exercise duration (min)	13.48 ± 1.94

4.2 Pre-LIST performance markers

Sprint times for 5_Rec (2.516 ± 0.115 s) were significantly slower than baseline (2.432 ± .087 s; $t_{(12)} = -2.816$, $P = .016$; Figure 4.1a). Although no differences were observed between

10_Rec (2.516 ± 0.161 s) and baseline (*P* > .017), 20_Rec was approaching significance (2.520 ± .124 s; $t_{(11)} = -2.460$, $P = 0.032$). Participant's time to complete the agility test were similar between the baseline assessment and all three experimental conditions (*P* > .017), although a trend for a slower agility time was observed for 20_Rec ($t_{(11)} = -2.471$; $P = 0.031$; Figure 4.1b). Similar findings were reported for VJ (Figure 4.1c), with a higher jump ability approaching significance during 10_Rec conditions ($t_{(12)} = -2.547$; $P = 0.026$).

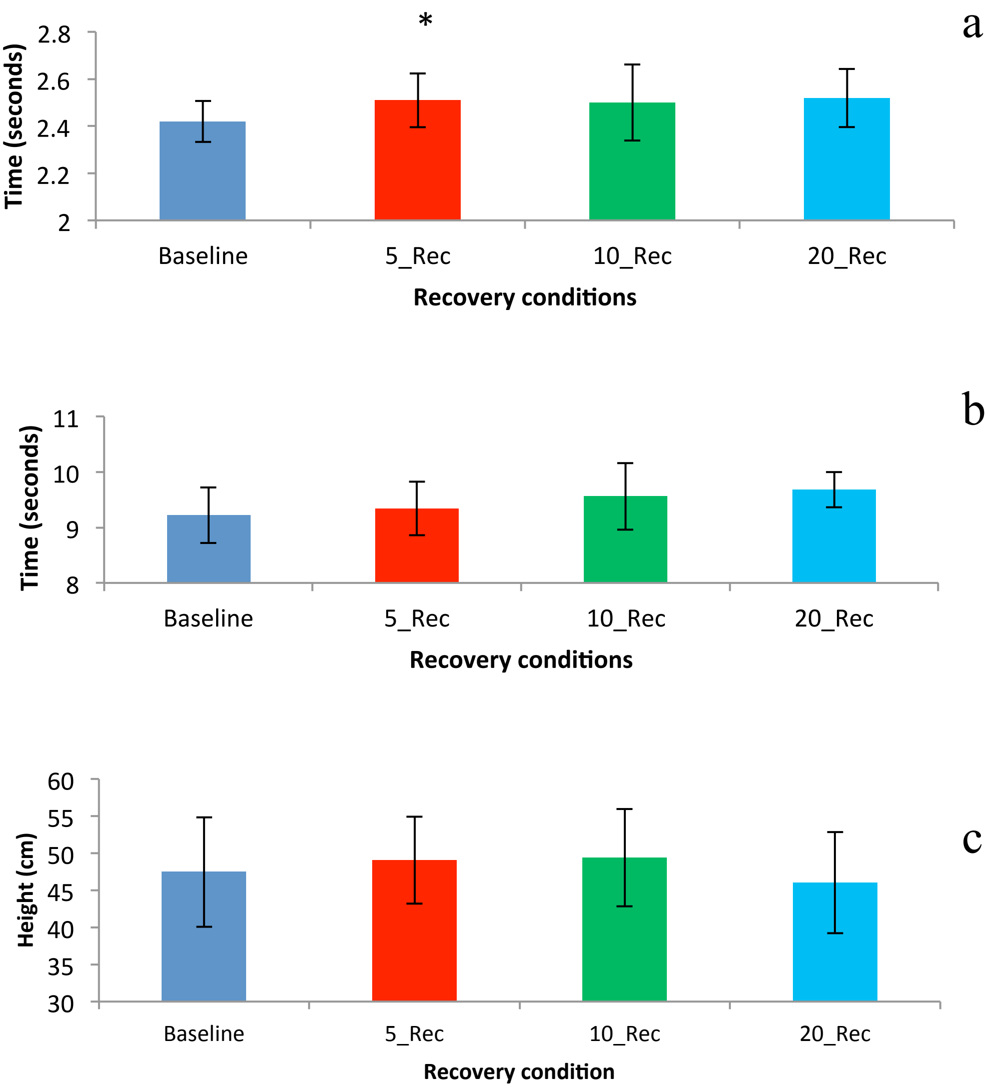

Figure 4.1: Mean (± SD) sprint (**A**), agility (**B**) and vertical jump (**C**) performance at baseline, 5-Rec, 10_Rec and 20_Rec.

* Significant difference between baseline and experimental trial (*P* <. .017).

4.3 Physiological and perceptual markers pre- and post-warm-up (WU)

There were no differences in body weight, resting heart rate and resting BLa at the start of each experimental trial (all *P* > .05; Table 4.2). Similar physiological and perceptual responses were observed between conditions when comparing BLa, FAS and FS post-WU (all *P* > .05; Table 4.3).

Table 4.2: Resting measures (pre-WU) of weight, HR and BLa. Data is reported as mean ± SD.

	5_Rec	**10_Rec**	**20_Rec**
Weight (Kg)	76.0 ± 7.7	76.0 ± 7.9	76.1 ± 8.3
Heart rate (b·min^{-1})	66 ± 9	65 ± 12	66 ± 14
BLa resting (mmol/L)	1.35 ± .36	1.34 ± .57	1.52 ± .94

Table 4.3: Post WU BLa, FS and FAS. Data is reported as mean ± SD.

	5_Rec	**10_Rec**	**20_Rec**
BLa (mmol/L)	2.60 ± 1.21	2.80 ± .98	2.71 ± 1.02
FAS	3.77 ± 1.30	3.69 ± 1.44	3.15 ± 1.63
FS	2.92 ± 1.71	2.46 ± 1.13	1.85 ± .99

4.4 Physiological and perceptual markers following 5, 10 and 20 min recovery duration

Despite a similar BLa response between conditions (*P* > .05), a significant difference for HR was observed on completion of the recovery period ($F_{(2, 22)} = 7.162$, $P < .01$; Table 4.4). Post-hoc analysis revealed HR to be significantly lower for 20_Rec compared to 5_Rec ($t_{(12)} = 1.720$, $P = .002$). Similar findings were noted for FAS ($F_{(1.4, 15.0)} = 6.600$, $P = 0.015$), although 20_Rec was only lower than 10_Rec ($P = 0.002$). FS levels were also significantly different between conditions ($F_{(2, 22)} = 15.963$, $P = 0.015$), with the 20_Rec being statistically lower than both 5_Rec and 10_Rec (both $P < .001$).

Table 4.4: Means ± SD for BLa, HR, FAS and FS after 5_Rec, 10_Rec and 20_rec.

	5_Rec	10_Rec	20_Rec
BLa (mmol/L)	2.51 ± .83	2.41 ± 1.17	1.94 ± 1.13
Heart rate ($B \cdot min^{-1}$)	84.9 ± 13.0	80.2 ± 10.0	73.6 ± 11.3 *
FAS	2.80 ±1.14	2.20 ± 1.69	1.50 ± .97 #
FS	3.17 ± 1.33	2.42 ± 1.62	.50 ± 1.88 #

*Significant difference between 20_Rec and 5_Rec ($P \leq .05$).

Significant difference between 20_Rec and 10_Rec ($P \leq .05$).

4.5 Physiological and perceptual markers during LIST

During the LIST, a significant test main effect was observed for BLa ($F_{(2, 22)} = 3.097$, $P < .05$). Post-hoc analysis revealed this difference to be between 10_Rec and 20_Rec ($P < .05$). There was however no test by time interaction ($P > .05$; Table 4.5). A trend for a time main effect was however noted ($F_{(2, 22)} = 2.752$, $P = 0.086$); within subject contrasts showed this difference to be greatest between blocks 1 and 3 ($F_{(1, 11)} = 5.487$, $P = 0.039$).

Table 4.5: Measures of BLa, HR, RPE, FAS and FS under the different condition (5_Rec, 10_Rec and 20_Rec) during the five blocks of LIST. Data is reported as mean ± SD.

		Block 1	**Block 2**	**Block 3**	**Block 4**	**Block 5**
BLa (mmol/L)	5_Rec	3.83 ± 1.17		6.18 ± 3.46		4.36 ± 2.18
	10_Rec	4.61 ± 1.64		5.6 ± 3.27		4.86 ± 2.94
	20_Rec	3.46 ± 1.56		4.58 ± 2.47		4.67 ± 3.57
Heart rate ($b \cdot min^{-1}$)	5_Rec	171 ± 16	171 ± 16	171 ± 18	170 ± 17	170 ± 18
	10_Rec	171 ± 14	171 ± 14	171 ± 14	169 ± 15	171 ± 15
	20_Rec	165 ± 17	168 ± 19	169 ± 18	168 ± 16	169 ± 17
RPE	5_Rec	12.4 ± 0.9	13.3 ± 1.1	14.0 ± 1.9	15.5 ± 1.7	16.3 ± 1.5
	10_Rec	11.8 ± 1.4	13.2 ± 1.1	14.3 ± 1.4	14.9 ± 1.2	15.9 ± 1.6
	20_Rec	12.8 ± 1.4	13.8 ± 1.7	14.6 ± 1.6	15.8 ± 2.0	17.2 ± 1.3
FAS	5_Rec	3.75 ± 0.87	3.5 ± .67	3.25 ± .97	2.92 ± .1.44	2.58 ± 1.44
	10_Rec	3.50 ± 1.17	3.17 ± .72	3.17 ± .84	3.00 ± 0.95	2.67 ± .99
	20_Rec	2.58 ± 0.90	2.83 ± 1.12	2.25 ± .97	2.08 ± 1.17	1.75 ± .75
FS	5_Rec	1.75 ± 1.06	1.50 ± 1.45*	0.5 ± 1.51	-0.75 ± 1.66	-1.75 ± 1.77
	10_Rec	1.58 ± 1.38	1.33 ± 1.16	0.75 ± 1.36	-0.17 ± 1.47#	-1.17 ±1.95
	20_Rec	0.33 ± 1.37	0.17 ± 1.47	-0.42 ± 1.56	-1.00 ± 1.95	-1.75 ± 1.91

*Significant difference between blocks 2 and 5 for 5_Rec ($P < .05$)

#Significant difference between blocks 4 and 5 for 10_Rec ($P < .05$)

A similar HR and RPE response was observed between conditions as there was no test or time main effects, nor test by time interactions for both measures (all $P > .05$). When considering the FAS, a significant difference was noted between conditions ($F_{(2, 22)} = 5.978$, $P < .01$; Table 4.5). FAS was significantly higher throughout 5_Rec (3.20 ± 1.2; $t_{(59)} = 5.663$, $P < .001$) and 10_Rec (3.10 ± 1.0; $t_{(59)} = 4.973$, $P < .001$) than 20_Rec (2.30 ± 1.0). As expected, FAS significantly decreased throughout the LIST ($F_{(4, 44)} = 6.322$, $P < .001$) with pairwise comparisons showing this difference to be largest between blocks 3 and 5 ($P < 0.05$). There was no test by time interaction ($P > .05$).

A test main effect ($F_{(2, 22)} = 3.417$, $P = .051$) and test by time interaction ($F_{(8, 88)} = 2.270$, $P = .030$) was shown for FS. The FS for 5_Rec (0.25 ± 1.98; $t_{(59)} = -3.829$, $P < .001$) and 10_Rec (0.47 ± 1.76; $t_{(59)} = 4.764$, $P < .001$) were significantly higher than 20_Rec (-0.53 ± 1.79). With regards to the observed interaction, Tukeys HSD revealed a significant decline in

FS between blocks 2 and 5 for 5_Rec, and between blocks 4 and 5 for 10_Rec (all $P \leq .05$; Table 4.5).

4.6 Sprint times

As demonstrated in Figure 6, although sprint times during LIST significantly increased ($F_{(1.8, 19.7)} = 12.286$, $P < .001$), they were not influenced by the recovery duration ($P > .05$).

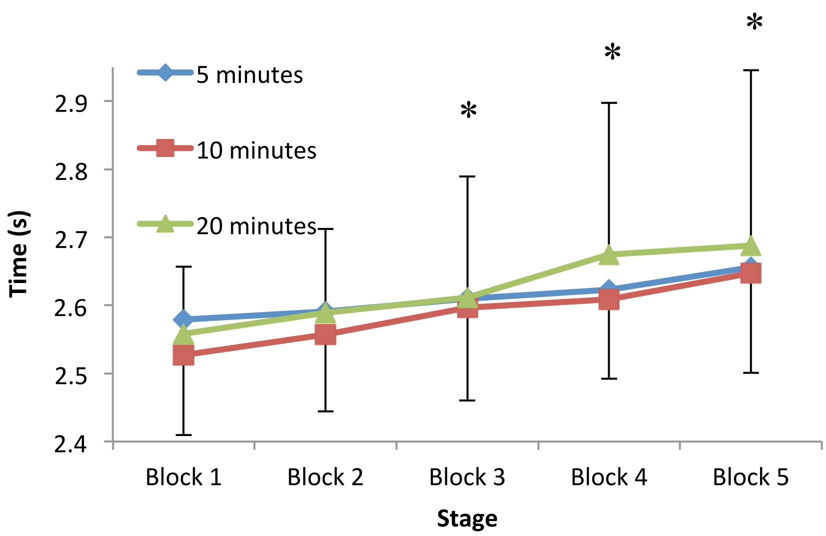

Figure 4.2: Mean ± SD times during the LIST protocol under 3 different recovery conditions (5_Rec, 10_Rec and 20_rec).

* Significant difference in sprint times between a block and a preceding block ($P < .05$).

4.7 Time to exhaustion

The exercise duration of the LIST time to exhaustion test was statistically similar between conditions (10.8 ± 7.1, 10.6 ± 4.7 and 8.0 ± 5.5 min for 5_Rec, 10_Rec and 20_ Rec, respectively; $P > 0.05$).

4.8 Physiological and perceptual markers following the completion of LIST

There were no significant differences in BLa levels, FAS, FS, HR, RPE or body weight between conditions on completion of the LIST (all $P > .05$). There was also no difference in the amount of water consumed nor the net weight lost during testing ($P > .05$; Table 4.6).

Table 4.6: Weight changes and water consumed during LIST protocol for different recovery durations (5_Rec, 10_Rec and 20_Rec). Data is reported as mean ± SD.

	5_Rec	**10_Rec**	**20_Rec**
Pre-weight (Kg)	76.0 ± 7.7	76.0 ± 7.9	76.1 ± 8.3
Post-weight (Kg)	75.0 ± 7.9	75.1 ± 8.3	75.3 ± 8.3
Water consumed (mL)	1189 ± 479	1286 ± 549	1150 ± 454
Net weight loss (Kg)	1.9 ± .4	1.9 ± .4	1.9 ± .5

Chapter 5: Discussion

This study assessed the effect of a 5, 10 and 20 minute recovery duration post WU on physical performance and perceptual responses of local football players during the LIST. The results from this study would suggest that ~ 10 minute recovery duration following an active WU may be most beneficial for sprinting, VJ performance and perceptual responses (FAS, FS) during a football match. The aforementioned finding supports the original hypothesis which postulated that 5 minute recovery duration would be too short to enable sufficient recovery from the WU. Alternatively a 20 minute recovery duration could be too long for WU benefits to still positively influence performance. However the BLa and HR results produced during the LIST would suggest little physiological difference between conditions thus suggesting perceptual markers are affected most by recovery duration. Therefore it is difficult to truly elucidate whether any recovery duration was more effective than the other conditions.

Performance effects

Sprint, Agility and VJ

Findings from the current study demonstrated a trend in the sprint and agility performance tests being most adversely impacted following the longest recovery duration (20_Rec). These findings complement earlier research with swimming (Zochowski, Johnson, & Sleivert, 2007) (West, et al., 2012). For example, both Zochowski et al. (2007) and West et al. (2012) reported a greater impairment in swim time trial performance in experimental conditions which involved longer recovery durations (45 mins cf. 10 mins and 45 cf. 20 min, respectively). As muscle temperature is particularly important for performance of power based activities, it may be suggested that the observed findings be due to cooler muscle temperatures following 20_Rec (Bell & Ferguson, 2009; De Ruiter & De Haan, 2000).

A detrimental effect on sprinting ability was also observed for 5_Rec, with participants completing the 15 m sprint distance in a statistically longer duration. This diminished performance is somewhat surprising given previous research around performance benefits of increasing muscle temperature (Needham, Morse, & Degens, 2009). Performance improvements have been shown following active WU (Stewart, Adams, Alonso, Koesveld, & Campbell, 2007), with additional benefits also being displayed following dynamic stretching protocols (Fletcher & Jones, 2004). However, as such research has not reported the recovery duration between WU and testing, the effect of a short recovery duration (5_Rec) is as yet unexplained. A higher rate of fatigue during 5_Rec may be a pertinent reason for the observed findings, as 5_Rec may be inadequate time for substrates to be replenished (Dawson, et al., 1997). While resynthesis of substrates is initially rapid, muscle biopsies show that 6 minutes after exercise, substrates were only at 85% of pre exercise levels (Bogdanis, Nevill, Boobis, Lakomy, & Nevill, 1995); an effect that may have inhibited optimal performance (McMahon & Jenkins, 2002). The influence of PAP may have had an effect on some members of the group, although the lack of resistance exercise in this studies WU protocol would suggest this is unlikely to produce a statistical effect (Chiu, Fry, Weiss, Schilling, Brown, & Smith, 2003). Previous research has shown some individual football players to note improvements in jumping and sprinting performance following WU (Till & Cooke, 2009). However this result suggests that after 5_Rec the influence of fatigue overrode any potential benefits of PAP (Hodgson, Docherty, & Robbins, 2005).

Interestingly, 10_Rec appeared to show an improved ability in VJ performance and was the only condition that suggested the WU was beneficial for athletic performance. Previous research supports an increased performance in VJ following WU (Holt & Lambourne, 2008), and crucially has been shown to only last for the first 6-10 minutes of recovery time; following which performance is decreased compared to baseline (Faigenbaum, McFarland, Kelly, Ratamess, Kang, & Hoffman, 2010). However, as Faigenbaum and colleagues retested participants every 2 minutes during the recovery period, the validity of the observed findings may be disputed. Conflicting research suggests that there is a linear decrease in performance after WU, with a 13% decline at 10 minutes which increases to 20% at 40 minutes post WU (Galazoulas, Tzimou, Karamousalidis, & Mougios, 2012). This decrease in jumping ability also showed a strong correlation with decreasing muscle temperature. This helps to support the theory of temperature related mechanisms being responsible for performance decrements.

While muscle temperature was not directly measured in this study, an increase in muscle temperature has been shown following similar WU's completed by participants in this study (Saltin, Gagge, & Stolwijk, 1968; Kenny, Reardon, Zaleski, Reardon, Haman, & Ducharme, 2003; Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004). Temperature then declines with the cessation of WU, with significant decrements occurring over 15-20 minutes, resulting in attainment of levels similar to resting (Saltin, Gagge, & Stolwijk, 1968). This would suggest that during the current study, participants muscle temperature would have decreased significantly following 20_Rec but would still have been elevated during 5_Rec and 10_Rec. Temperature related mechanisms for this potential improvement of VJ for 10_Rec and decrement in performance for 20_Rec include a rightward shift in force/velocity curve, increased speed of nerve conduction and decreased muscle stiffness (Volianitis, Koutedakis, & Carson, 2001). Explosive exercises such as sprinting, agility tests and VJ, will be positively influenced by the increased power and rate of muscle contraction, which is brought about by these mechanisms.

Sprints during LIST

Despite the observed findings in sprint performance pre-LIST, the recovery duration had no statistical effect/influence on sprint performance during the LIST. As expected, sprint performance deteriorated during the LIST (Figure 4.2). This is similar to previous research that has shown similar decrements in sprint performance during the LIST (Ali, Gardiner, Foskett, & Gant, 2011) (Bailey, et al., 2007). The observed findings are most likely due to fatigue, which may be attributed to a decreased activation of the motor unit combined with exhaustion of metabolic factors (Mendez-Villanueva, Hamer, & Bishop, 2008; Girard, Mendez-Villanueva, & Bishop, 2011).

Time to exhaustion during the LIST

The time to exhaustion in this study (10.8 ± 7.1, 10.6 ± 4.7 and 8.0 ± 5.5 min for 5_Rec, 10_Rec and 20_ Rec, respectively) are similar to those reported in previous research studies (Nicholas, Nuttal, & Williams, 2000) (Ali, Gardiner, Foskett, & Gant, 2011), although no statistical differences in time to exhaustion were observed between conditions. As there is no previous research investigating recovery duration and endurance performance, it is difficult to rationalize this result. However, the extended period of time that has elapsed between WU and the exhaustive element of LIST may be a potential explanation. Previous research investigating recovery time on performance, has used shorter testing protocol and attributed many of the performance benefits to temperature related mechanisms (Zochowski, Johnson, & Sleivert, 2007; West, et al., 2012). As muscle temperature reaches equilibrium after approximately 20 minute of exercise, by the stage participants reached the exhaustive element of LIST, muscle temperature differences between conditions would have been negated (Bishop, 2003a).

Physiological responses pre, during and post LIST

Blood lactate

Despite there being, as expected, similarities in BLa at rest and post-WU between conditions, there were no differences prior to LIST. This is surprising when considering that lactate clearance should be greater following a longer recovery and during the prescribed rest periods of the LIST, BLa should be oxidized and removed from the blood (Gladden, 2000). Given that subjects performed all three conditions, the clearance rates should be the same and thus not a confounding factor (Thomas, Sirvent, Perry, Raynaud, & Mercier, 2004). However previous research in swimming, which used varied recovery durations found that even when recovery duration following WU doubled, lactate levels remained similar (West, et al., 2012; Zochowski, Johnson, & Sleivert, 2007). Reasoning behind this is unknown but could be attributed to a combination of human error, small sample size and unreliable measurement apparatus. Although previous research has demonstrated the lactate pro to be a reliable measure of BLa (Tanner, Fuller, & Ross, 2010; Pyne, Boston, Martin, & Logan, 2000), the primary investigator noted high intra-individual variation in this study. This may be a principal reason for the observed findings.

Several significantly different BLa readings were found during the first segment of LIST with a large difference between blocks 1 and 3 testing and a generally higher value following 10_Rec compared to 20_Rec. An increase in BLa is expected with the repeated sprint design of the protocol. Comparable results have been shown in another study using LIST, and similarly these increases did not continue into the later stages of segment 1 (Patterson & Gray, 2007).

While BLa would be expected to increase with repeated sprint activity, previous research has documented a blunted BLa response following active WU. As it remained lower than 10_Rec during the LIST, it could be suggested that 20_Rec was able to elicit a more pronounced WU effect (Wittekind & Beneke, 2011). Although without an associated performance increase, this result must be questioned. BLa levels in general were lower than those found during the original LIST investigation where values approximately ranged from 6-8mmol.L^{-1} compared to the approximate range of 3.5-6 mmol. L^{-1} observed in this current study (Nicholas, Nuttal, & Williams, 2000).

Measures of BLa following the completion of testing showed no difference between conditions which conflicts with other research which showed higher levels post testing despite similar levels prior to exercise (West, et al., 2012). This was associated with a large performance enhancement from the group showing higher lactate levels, perhaps suggesting participants were producing more lactate as a product of increased work output. However, results for BLa in the literature appear mixed, as another very similar study to West et al., found no effect for recovery duration at any time point (Zochowski, Johnson, & Sleivert, 2007).

Heart rate

HR levels were comparable across conditions following the completion of WU, which suggests good reproducibility of WU protocol (Achten & Jeukendrup, 2003). As expected the varied recovery durations produced significant HR differences, with increased recovery time correlating with lower HR levels (Kannankeril, Le, Kadish, & Goldberger, 2004). There was no time or condition effect on HR during LIST and values were typically maintained between 165-171 $b \cdot min^{-1}$ throughout the LIST (Appendix H). There was also no difference in HR at the completion of testing. Similar findings have been produced by research investigating varied recovery durations during swimming (West, et al., 2012). While another study which had more disparity in recovery duration, found that the lower HR of the increased duration was sustained through to the end of performance testing (Zochowski, Johnson, & Sleivert, 2007).

Perceptual effects

Recovery duration had a large effect on arousal and positive feelings throughout the experimental procedure. Markers for feelings and arousal (FS, and FAS) showed significant changes during exercise. Similar results from previous studies were shown for RPE which was unaffected by recovery duration at any stage of testing (West, et al., 2012).

FAS and FS

In further support of WU equality, values for FAS and FS were similar between conditions following WU (Table 4.3). Following the recovery duration, 20_Rec, initiated a lower FAS than 10_Rec, while FS after 20_Rec was lower than both the 5 and 10 minute recovery durations (Table 4.4). FAS then remained elevated during LIST for 5_Rec and 10_Rec compared to 20_Rec. Collectively across all conditions, FAS decreased during LIST, with the biggest differences being between blocks 3 and 5. FS was also higher than 20_Rec following 5_Rec and 10_Rec with further analysis showing the greatest decline for 5_Rec occurred across the scope of stages while 10_Rec had its biggest change between blocks at the end of LIST (Table 4.5). The novel nature of this study means that comparison of perceptual feelings following varied recovery durations is hard to perform. Applicable studies into swimming and basketball recovery durations, have failed to address the perceptual aspect on participants other than measuring RPE values (West, et al., 2012; Galazoulas, Tzimou, Karamousalidis, & Mougios, 2012; Zochowski, Johnson, & Sleivert, 2007).

These results would suggest that participants were able to maintain positive mental affects of WU for 10 minutes however 20_Rec was long enough for effects to dissipate. The drop off in FAS between blocks 3 and 5 of the LIST coincides with 45 minutes of exercise being expended. As this is also the duration of half of a football match, there may be an association with the normal 15 minute break being absent causing the decreased FAS scores. Use of the LIST protocol for carbohydrate supplementation studies has shown to cause a gradual decline in both FAS and FS, in similar decrements to those reported in this study (Backhouse, Ali, Biddle, & Williams, 2007). The influence on perceptual markers of varied recovery durations has however not been previously investigated.

The 20_Rec was long enough for pleasurable feelings (FS) to decrease during a seated squat procedure and this is likely to have a physiological basis relating to temperature and in particular increased muscle and joint stiffness (Girard, Carbonnel, Candau, & Millet, 2009). Breaking of actin myosin bonds in response to temperature increases caused by WU can help to decrease resistance and make movement more fluent (McNair & Stanley, 1996; Bishop, 2003a). The decrease of FS as exercise time increased has been shown previously during the LIST (Ali, Gardiner, Foskett, & Gant, 2011), however why 20_Rec remained lower throughout testing has not been addressed in the literature.

Limitations

Temperature

Perhaps the largest limitation involved with this research was the absence of temperature measurements, in particular following the recovery durations after the WU. As many of the proposed WU benefits are temperature related, being able to quantify how temperature changed during this period would have been invaluable (Bishop, 2003a; Brajkovic & Ducharme, 2005; Brunner-Ziegler, Strasser, & Haber, 2010). This would also have allowed comparisons with similar studies investigating other sports and varied recovery durations (West, et al., 2012; Galazoulas, Tzimou, Karamousalidis, & Mougios, 2012). The practicalities of this study made the measurement of temperature before and during the LIST not possible.

Limitations of LIST

Football specific skills

The protocol used in this study does not take into account the movements and skill required with football in relation to match play. In order to consider the skill aspect of football, some studies using LIST have modified the protocol to include tests of passing, control and shooting ability (McGregor, Nicholas, Lakomy, & Williams, 1999; Ali, Gardiner, Foskett, & Gant, 2011; Ali & Williams, 2009). As this was a preliminary investigation into the effects of recovery duration, the LIST protocol used only measured physical characteristics of participants. Future studies in this area could include football specific testing similar to those mentioned above, in an effort to investigate if the skill dimension of football is affected by longer recovery durations. The ability to balance while performing tasks has been shown to take longer to recover following exhaustive exercise with 20 minutes being suggested for full recovery (Khanna, Kapoor, & Zutshi, 2008). This may mean that football skills, which require balance for optimal results, may be affected by the shorter periods of recovery time. Fatigue has been shown to decrease football skill level during matches and as such recovery durations which alter fatigue levels may modify performance (Rampinini, Impellizzeri, Castagna, Coutts, & Wisløff, 2009).

Running surface

Due to the unpredictability and complex nature of a football game, experiments performed in controlled environments will only be approximations of its physical demands and as such will have several limitations (Impellizzeria, Rampininia, & Marcorab, 2005). The surface which participants were running on in this study was a hard wooden floor which provides a different level of compliance to a football field used during matches. This can have an energy cost and change the way that participants run, which combined could contribute to subtle performance changes (Kerdok, Biewener, McMahon, Weyand, & Herr, 2002; Hardin, Van Den Bogert, & Hamill, 2004). In this study, the location was selected to avoid complications with both changing weather conditions and the cost of hiring artificial turf facilities.

Halftime period

The LIST protocol replicates a football match well in terms of duration and other physical markers but it does not take into account the normal 15 minute break for half time (Nicholas, Nuttal, & Williams, 2000; Magalhães, Rebelo, Oliveira, Silva, & Marques, 2010). In LIST this break is replaced by 3 minute rest period after each 15 minute exercise block. While total time spent resting mat be similar, the longer period of continuous rest in actual matches may have more physiological implications. For example, measurements of muscle temperature have shown a 2˚C decrease over the half time break and crucially this decreased sprint performance at the beginning of the second half by 2.4% (Mohr, Krustrup, Nybo, Nielsen, & Bangsbo, 2004). This also supports recovery duration of less than 15 minutes, to avoid inhibiting sprinting performance at the beginning of competition, albeit the prior football in this study must be considered.

Future research

Associated areas of future research could include:

- Methods for maintaining muscle temperature during interim period. This may include heat pads or heated/compression clothing.
- Investigating recovery duration on skill and balance elements, possibly through use of modified LIST.
- Replication of similar trials with a female cohort and increased participant numbers.

Conclusions and applications

This study supports the theory that 20_Rec may be too long for maximal benefits to be conveyed from a WU protocol. Conversely 5_Rec would be too short to allow full recovery to take place which may inhibit performance. Therefore a duration of 10_Rec following WU could be implemented to ensure that maximal performed once competitive matches begin. As scheduling for official FIFA matches is unlikely to change due to television and sponsorship restrictions, optimal performance may require players to continue some form of WU in the changing rooms prior to match ceremonies beginning. Future research could investigate possible methods for maintaining muscle temperature in this interim period. Some interventions that could be trialed include heating clothing, heat pads or having players cycling on exercycles whilst receiving the coach's final instructions.

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Appendices

Appendix A

Pre-Exercise Health Screening Questionnaire

Name:____

Address: ____

Phone: _________________________________

Age: ________________

Please read the following questions carefully. If you have any difficulty, please advise the exercise specialist who is conducting the exercise test.

Please answer all of the following questions by ticking only one box for each question:

This questionnaire has been designed to identify the small number of persons (15-69 years of age) for whom physical activity might be inappropriate. The questions are based upon the Physical Activity Readiness Questionnaire (PAR-Q), originally devised by the British Columbia Dept of Health (Canada), as revised by [1]Thomas *et al.* (1992) and [2]Cardinal *et al.* (1996), and with added requirements of the Massey University Human Ethics Committee. The information provided by you on this form will be treated with the strictest confidentiality.

Qu 1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

Yes ☐ No ☐

Qu 2. Do you feel a pain in your chest when you do physical activity?

Yes ☐ No ☐

Qu 3. In the past month have you had chest pain when you were not doing physical activity?

Yes ☐ No ☐

Qu 4. Do you lose your balance because of dizziness or do you ever lose consciousness?

Yes ☐ No ☐

Qu 5. Are you currently using prescription medication?

Yes ☐ No ☐

Qu 6. Do you have a bone or joint problem that could be made worse by vigorous exercise, particular in the lower back and/or legs?

Yes ☐ No ☐

Qu 7. Do you have any pre-existing muscular problems or injuries that may be aggravated by repetitive, vigorous physical activity?

Yes ☐ No ☐

Qu 8. Do you know of any other reason why you should not do physical activity?

Yes ☐ No ☐

Qu 9. Have any immediate family members had heart problems prior to the age of 55?

Yes ☐ No ☐

Qu 10. Have you been hospitalised recently?

Yes ☐ No ☐

Qu 11. Are you diabetic?

Yes ☐ No ☐

Qu 12. Do you currently or have you previously had renal and/or hepatic disease?

Yes ☐ No ☐

Qu 13. Do you have any infectious disease that may be transmitted in blood?

Yes ☐ No ☐

You should be aware that even amongst healthy persons who undertake regular physical activity there is a risk of sudden death during exercise. Though extremely rare, such cases can occur in people with an undiagnosed heart condition. If you have any reason to suspect that you may have a heart condition that will put you at risk during exercise, you should seek advice from a medical practitioner before undertaking an exercise test.

I have read, understood and completed this questionnaire.

Signature: ____ Date: ___________________

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ACSM Coronary Artery Disease Risk Stratification Assessment

(This document is to guide the researcher through the risk stratification procedures)

The main purpose of pre-participation screening is to identify individuals at increased risk of cardiovascular injury or death during exercise. To this end, the client should complete the physical activity readiness questionnaire (PAR-Q, attached)

Cardiovascular disease risk factor profile

Cardiovascular disease (CVD) is an umbrella term referring to the diseases of the heart and circulatory system. Around 50% of CVD deaths are due to coronary heart disease and around 25% are due to stroke. It is important to determine an individual's CVD risk factor profile because CVD is the main cause of exercise-induced death in middle-aged men. Table 1 lists the risk factors that are typically assessed in determining an individual's CVD risk factor profile.

- Family history is assessed because the presence of premature CVD in first-degree relatives is associated with a two- to six-fold increase in CVD risk. Enter 1 if the client's father or brother suffered a heart attack before 55 or if the client's mother or sister suffered a heart attack before 65 years-of-age.
- The CVD death rate of smokers is at least twice that of non-smokers. Enter 1 if the client has smoked at all in the last six months.

- There is a linear relationship between blood pressure and CVD risk. Measure blood pressure in accordance with the procedures described in Box 1 and enter 1 if systolic blood pressure is ≥140 mm Hg or if diastolic blood pressure is ≥90 mmHg.
- Compared to men with desirable cholesterol levels, the six-year CVD death rate is twice as high in men with concentrations ≥5.25 $mmol{\cdot}l^{-1}$ (Stamler, Wentworth, & Neaton, 1986). Measure total cholesterol in accordance with the procedures described in Box 2 and enter 1 if the fingerprick concentration is >5.2 $mmol{\cdot}l^{-1}$.
- Fasting blood glucose is assessed because most diabetics are at increased risk of CVD. Measure blood glucose in accordance with the procedures described in Box 2 and enter 1 if the fingerprick concentration is >6.1 $mmol{\cdot}l^{-1}$ on at least two separate occasions. Non-fasting blood glucose concentration should be <11.1 $mmol{\cdot}l^{-1}$.
- Body mass index (BMI) and waist girth are determined because obesity predisposes to diabetes and heart disease. Measure height, weight and waist girth as described in Box 3 and enter 1 if BMI is greater than 30 $kg{\cdot}m^2$ or if waist girth is >102 cm in men or >88 cm in women.
- Enter 1 if the client does not undertake 30 minutes of moderate-intensity physical activity on three or more days of the week or if the client is not engaged in a exercise programme consisting of around 20 minutes of vigorous activity on three or more days of the week.
- CVD is not inevitable, but age is an indirect measure of an individual's exposure to other risk factors. Enter 1 if the client is a man older than 45 or a woman older than 55.
- HDL-cholesterol fights atherosclerosis and every 0.026 $mmol{\cdot}l^{-1}$ increase in HDL-C reduces CVD risk by 2–3% (Gordon et al., 1989). Accordingly, high HDL-C is regarded as a 'negative risk factor' and a concentration >1.6 $mmol{\cdot}l^{-1}$ removes 1 score from the total risk factor count. Enter 0 if HDL-C concentration is unknown.

Subtract the negative risk factor count from the sum of positive risk factors to determine the risk factor score. 'Low-risk' individuals are asymptomatic men ≤45 years and asymptomatic women ≤55 years whose risk factor score is no more than one. Low-risk individuals can undergo a maximal exercise test and participate in moderate or vigorous exercise training. 'Moderate-risk' individuals are asymptomatic men >45 years, asymptomatic women >55 years, and, regardless of age, individuals whose risk factor score is two or more. Moderate-risk individuals can undergo a sub-maximal exercise test and can begin a programme of moderate-intensity exercise. It is recommended that moderate-risk individuals undergo a medical examination before engaging in vigorous exercise. 'High-risk' individuals are those with signs or symptoms of heart disease, as indicated by any 'yes' answer on the PAR-Q. High-risk individuals should consult their GP before engaging in exercise testing or exercise training. Moderate-intensity exercise is that below the lactate threshold, which is equivalent to RPE 12–13 or a positive talk test. Vigorous-intensity exercise is that between the lactate threshold and the lactate turnpoint, which is equivalent to RPE 14–16 or an equivocal talk test (Persinger, Foster, Gibson, Fater, & Porcari, 2004).

Table 1. Risk factor counting and interpretation for exercise testing and exercise prescription

	enter 1 for yes or 0 for no
Family history*	______
Current smoker or smoker in last six months	______
SBP ≥140 *or* DBP ≥90 mm Hg	______
Total cholesterol >5.2 $mmol \cdot l^{-1}$	______
Fasting blood glucose ≥6.1 $mmol \cdot l^{-1}$†	______
BMI ≥30, or waist girth >102 cm in men or >88 cm in women‡	______
Sedentary§	______
Age >45 if male or >55 if female	______
Sum of positive risk factors (A):	☐
HDL-C >1.6 $mmol \cdot l^{-1}$	______
Negative risk factor count (B):	☐
Risk factor score (A–B):	☐
Does the participant have any blood-borne diseases or bleeding disorders?	______

*Family history refers to heart attack in father or brother before age 55 or mother or sister before age 65. † Impaired fasting glucose should be confirmed by measurements on at least two separate occasions. ‡Waist girth should be measured with an inelastic tape in a horizontal plane at the narrowest part of the torso. §Sedentary refers to individuals not engaged in a regular exercise programme or those not undertaking 30 minutes of moderate-intensity physical activity on three or more days of the week.

Interpretation: 'Low-risk' individuals are asymptomatic men ≤45 years and asymptomatic women ≤55 years whose risk factor score is no more than one. Low-risk individuals can undergo a maximal exercise test and participate in vigorous exercise training. 'Moderate-risk' individuals are asymptomatic men >45 years, asymptomatic women >55 years, and, regardless of age, individuals whose risk factor score is two or more. 'Moderate-risk' individuals can undergo a sub-maximal exercise test and can begin a programme of moderate-intensity exercise. 'High-risk' individuals are those with signs or symptoms of heart disease, as indicated by any 'yes' answer on the PAR-Q. High-risk individuals should consult their GP before engaging in exercise testing or exercise training.

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Influence of duration between warm up and competition for elite football players

INFORMATION SHEET

Researcher(s) Introduction

You are being invited to take part in a research study by Terry O'Donnell, a post graduate student from within the School of Sport and Exercise Science at Massey University (Wellington). Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. If there is anything that is not clear or if you would like more information, please do not hesitate to contact me on the details provided below. Take time to decide whether or not you wish to take part. If you decide not to take part it is not a problem and we thank you for considering our request. If you decide to take part, you will be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time without prejudice or without giving a reason. Participants can even stop participating in the project during an exercise test.

What is the purpose of the study?

This study is investigating the amount of recovery time that occurs between warm up and the beginning of a football game. Methods of maintaining warm up benefits will also be studied; this will include the use of heat pads and compression garments. Large variations occur between different teams in the build up to competitions and this can lead to athletes muscles cooling down and negating prior warm up. The results of this study may be used to improve warm up protocols so that athletes are able to begin games in optimal condition to perform.

How are participants recruited?

Participants will be recruited from local football clubs in the Wellington area. Your chairperson/captain has been approached and informed about the study and agreed to circulate this information sheet on behalf of the researcher. This information sheet provides details of the study and what is asked in terms of participation. Those interested in taking part can contact Terry O'Donnell by email or telephone.

Are there any inclusion or exclusion criteria?

INCLUSION

- Healthy, trained male volunteers between the ages of 18 and 35 years.
- Engaged in regular training and competing in the premier Wellington football division or higher.
- Asymptomatic of illness or pre-existing injuries.
- Athletes must have a minimum maximal oxygen consumption (VO_2 max) of

50 $ml.kg^{-1}.min^{-1}$.

Risk stratification measures, including the assessment of blood glucose, total cholesterol, blood pressure and smoking status, will be assessed prior to the initial exercise test, as recommended by the American College of Sports Medicine (ACSM, 2010).

EXCLUSION

- Men over the age of 35 or below the age of 18
- Participants unable to attain 50 $ml.kg^{-1}.min^{-1}$ during a VO_2 max test
- Those who suffer from chest pains or heart trouble
- Personal history of diabetes, hypertension or vascular disease
- Muscular problems that may be aggravated by injury.

Participants will experience physical discomfort in each of the exercise tests. However, this feeling should be no different to the feelings usually encountered by athletes during training and competition.

What will I be asked to do if I agree to take part?

Firstly you will be asked to complete a Physical Activity Readiness Questionnaire (PAR-Q) at Massey University's Sport and Exercise Science Physiology Research laboratory (Wellington; 3C26). You will also have your height and weight measured along with various risk stratification measures (blood glucose, cholesterol, blood pressure etc). Your smoking history and family history of cardiovascular diseases will also be assessed. If you have one (depending on the severity of the risk factor), or two or more high risk-factors (i.e. high blood pressure, high blood glucose values) you will not be able to take part in the exercise component to the study. Under your direction, information from the health check-up may be made available to your GP.

Following risk assessment procedures, you will undertake a maximal oxygen consumption test on a treadmill. This will involve a staged test which will increase in intensity every three minutes until the point of exhaustion is reached. During this test your expired oxygen will be collected for analysis. From this data, your VO_2 max will be determined.

On performance testing days, you will be asked to bring all football gear used during games such as boots and uniforms to Wakefield park where testing will occur. You will perform a structured 25 minute warm up and will then be allowed to recover for either 5, 10 or 20 minutes with either no intervention, with heat pads on your legs or while wearing compression garments. Following the allotted recovery period, an agility test, a sprinting test and vertical jump test will be performed. The final performance test you will be asked to complete is the Loughborough intermittent shuttle test (LIST). The protocol for LIST involves a series of walking, jogging and sprinting over a distance of 20 meters which is designed to replicate a football match. It finishes with an exhaustion test with alternating shuttles at 55% and 95% of your VO_2 max.

Blood lactate will be measured at several occasions during performance testing from a fingerprick capillary sample. Fingerprick blood samples will be measured for glucose, cholesterol (risk stratification measures) and lactate, in accordance with Massey University's 'standard operating procedures'. Additionally heart rate will be continuously recorded during exercise, while muscle temperature will be measured with skin thermistors during rest periods. You will also be asked to use a 'feeling scale' during rest period to allow us to obtain some additional perceptual indicators.

Participants will be asked to provide approximately 8.5 hours of their time to take part in the study. This will include a 45 minute risk stratification assessment and VO_2 max test, and three performance test days at Wakefield park.

The compression garments that will be used are commercially available (Skins) lower limb, hip to knee compression tights. These compression stockings are composed of 76% nylon tactel microfiber, and 24% elastane. The garments are machine washable. Participants will wash the garment between time trials. There are no reported risks associated with wearing these garments. Participants will wear their own set of skins for the duration of the study. The compression garments will be supplied by © 2010 Skins™. Previous research completed by Dr. Faulkner has established a working relationship with Skins. It has been made clear at all times that Skins will have no influence over the progress of the study, nor control of data once the study has been completed. All other consumable costs will be supported by Dr James Faulkner's Massey University Research Account.

What are possible disadvantages and risks of taking part?

Testing will involve maximal effort exercise which will cause short term levels of exhaustion to the participants.

Delayed onset muscle soreness (DOMS) is likely to occur following performance testing.

Finger pricks for lactate measurements will cause minor discomfort to the subjects.

Potential discomfort caused by heat pads being too warm.

What are the possible benefits of taking part?

The potential benefits from this study are the identification of the optimal time between warm up and game commencement. This may allow warm up protocols to be altered to maximize performance. Measures of heart rate, blood lactate, sprint time, agility time and vertical jump may be used for monitoring of training and performance in subsequent training situations, and prescribing appropriate training intensities and thresholds. Measures of aerobic fitness will be found from the VO_2 max and LIST testing which can be used for training prescription. This information will be provided to the recruited participants and may lead to training modifications which may enable further improvements in performance.

What if something goes wrong?

Compensation of Injury.

If physical injury results from your participation in this study, you should visit a treatment provider to make a claim to ACC as soon as possible. ACC cover and entitlements are not automatic and your claim will be assessed by ACC in accordance with the Accident Compensation Act 2001. If your claim is accepted, ACC must inform you of your entitlements, and must help you access those entitlements. Entitlements may include, but not be limited to, treatment costs, travel costs for rehabilitation, loss of earnings and/or lump sum for permanent impairment. Compensation for mental trauma may also be included, but only if this is incurred as a result of physical injury.

If your ACC claim is not accepted you should immediately contact the researcher. The researcher will initiate processes to ensure you receive compensation equivalent to that which you would have been entitled had ACC accepted your claim.

Data Management

All information which is collected about you during the course of the research will be kept strictly confidential. You will be identified with an alpha-numeric code on all recording sheets. The data will be analysed as group means and individual participants' identities will not be disclosed on any documentation (other than signed consent form). The data will be kept for 5 years by Dr. Faulkner to allow the investigators to return to the source of the data if/when needed. All physical documents will be shredded after the due date, and all electronic data will be wiped from the hard drive.

Your rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- Decline to answer any particular question
- Withdraw from the study at the time of physical testing
- Ask any questions about the study at any time during participation
- Provide information on the understanding that your name will not be used unless you give permission to the researcher
- Be given access to a summary of the project findings when it is concluded.

What will happen to the results of the research study?

A summary of the research findings will be available electronically (or hard copy where necessary) to all participants. A detailed analysis of your individual results may also be provided to you at your request. The research findings will be submitted to a peer reviewed scientific journal for publication, and it is expected that the findings will also be presented at a national or international conference (i.e. European College of Sport Science, or Sports and Exercise Science New Zealand).

Who is organizing and funding the research?

The research will be organized and conducted by Terry O'Donnell who is a post graduate student at the School of Sport and Exercise. The research is funded by Massey University (Dr Faulkner's Personal Development Account).

Who may I contact for further information?

If you would like more information about the research before you decide whether or not to you would be willing to take part, please contact:

Terry O'Donnell

School of Sport and Exercise

Massey University

Private Bag 756

Wellington

Email: terry.odonnell77@gmail.com

Number: 0272041094

Dr James Faulkner

School of Sport and Exercise

Massey University

Private Bag 756

Wellington

J.Faulkner@massey.ac.nz

(04) 801 5799 62104

Thank you for your interest in this research study.

Committee Approval Statement

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 11/69. If you have any concerns about the conduct of this research, please contact A/Prof Hugh Morton, Chair, Massey University Human Ethics Committee: Southern A telephone 06 350 5799 x 4265, email humanethicsoutha@massey.ac.nz.

Influence of duration between warm up and competition for elite football players

PARTICIPANT CONSENT FORM - INDIVIDUAL

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: .... **Date:** ....

Full Name - printed ....

Appendices E

12 June 2012

Terry O'Donnell

1A Belvedere Road

Hataitai

WELLINGTON 6021

Dear Terry

Re: HEC: Southern A Application – 11/69

Influence of duration between warm up and competition for elite football players

Thank you for your letter dated 7 June 2012 outlining the change you wish to make to the above application.

The change, addition of a female cohort, has been approved and noted.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee. If over time, more than one request to change the application is received, the Chair may request a new application.

Yours sincerely

Dr Brian Finch, Chair

Massey University Human Ethics Committee: Southern A

cc	Dr James Faulkner	A/Prof Steve Stannard, HoS
	School of Sport & Exercise	School of Sport & Exercise
	WELLINGTON	**PN621**

Feeling Scale

-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
Very Bad		Bad		Fairly Bad	Neutral	Fairly Good		Good		Very Good

Felt Arousal Scale

6 High Arousal

5

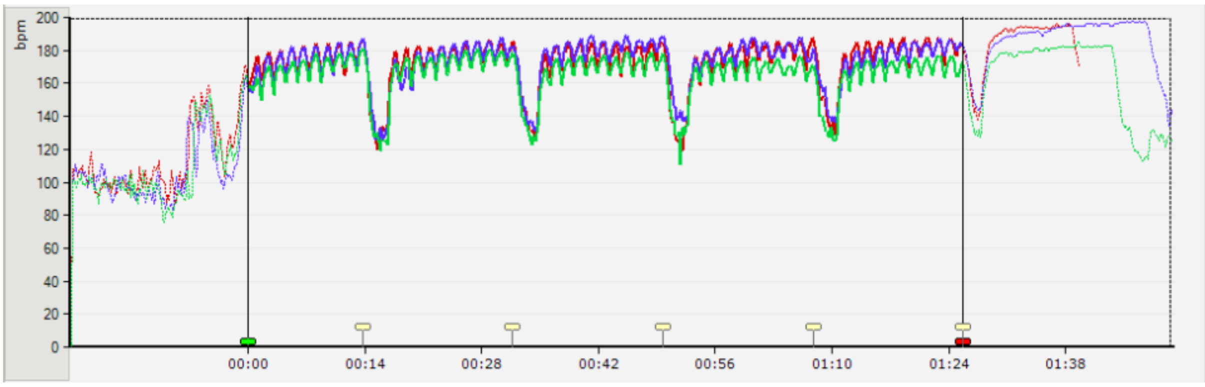
4

3

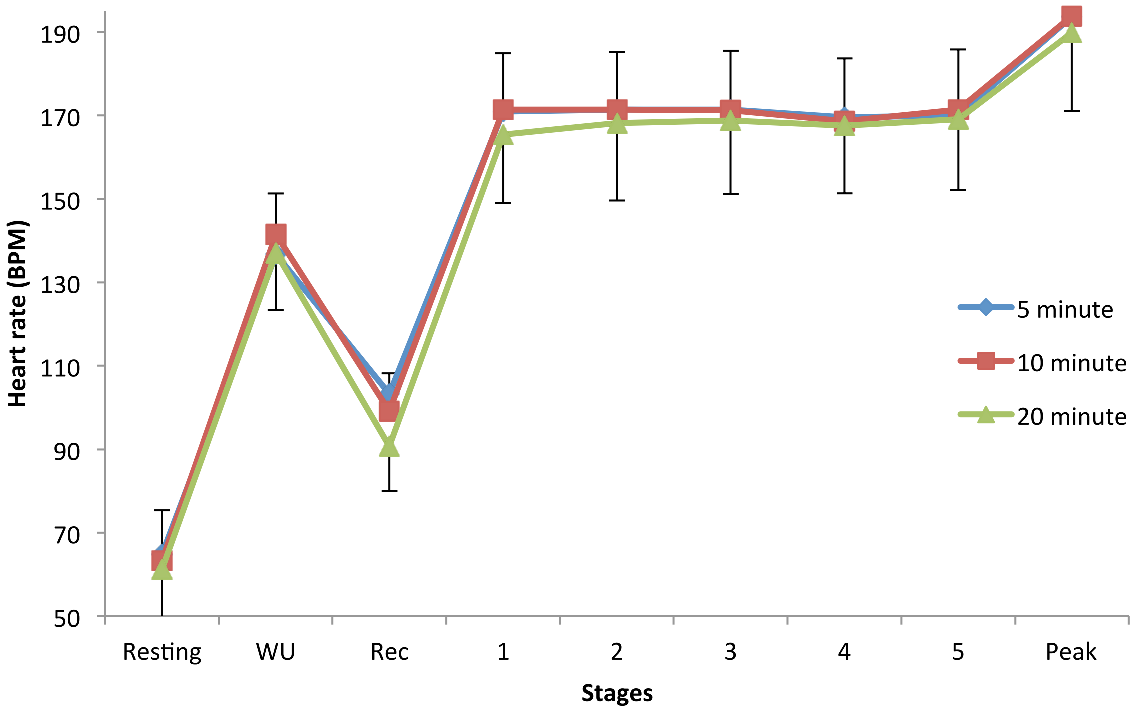
2

1 Low Arousal

Appendix H



Example Hr data from 3 participants during LIST testing



Heart rate values during the entire testing protocol for 5_Rec, 10_Rec and 20_Rec.