

The Effects of a Dryland Activation Protocol During the Transition Phase on Elite
Swimming Performance

by

Jeremy Bagshaw
Bachelor of Arts, University of California-Berkeley, 2015

A Thesis Submitted in Partial Fulfillment
of the Requirements for the Degree of

MASTER OF SCIENCE

in the School of Exercise Science, Physical and Health Education

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Supervisory Committee

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Abstract

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The purpose of the present study was to determine the effect of including a dryland activation during a 30-minute transition phase time between pool warm-up and competition on elite swimming performance. Previous research has shown the benefits of shorter transition times, or transition times that include dryland activation, improve swimming performance. Nine elite swimmers from the High-Performance Centre Victoria, 2 males and 7 females (18.7 ± 4.3 yrs), completed two testing sessions separated by one week, consisting of a 30-minute traditional (TRAD) or dryland (DL) transition phase followed by a 200-metre time-trial (TT). The swimmers swam the TT in their primary 200m event. Both transition phases were identical through the first 20-minutes but for the next 10 minutes, swimmers either sat quietly for 10 minutes (TRAD) or completed a 5-minute dryland activation 5 minutes pre-TT (DL). The dryland activation consisted of 2 sets of 40 seconds of jumping jacks and 6 explosive burpees completed self-paced but within a 5 minute time limit. Core temperature (T_{core}) and Heart Rate (HR) were measured throughout the entire testing sessions. TT performance was significantly faster ($p < .010$) following DL (130.61 ± 10.46 secs) compared to TRAD (131.71 ± 11.08 secs), an improvement of 0.84%. The third 50m split was also significantly faster ($p < 0.18$) following DL (34.83 ± 4.28 secs) compared to TRAD (35.47 ± 4.47 secs). Heart rate was significantly elevated following the dryland activation compared to the same time in TRAD (134 ± 22 vs. 84 ± 13 bpm, $p < 0.001$). There were

no significant differences in T_{core} between the two transition phase conditions. The results from this research support the inclusion of a dryland activation during the transition phase of elite swimming competitions. As the smallest of differences can influence final placing at international level swimming competitions, the small gains found in the present study may have considerable implications for optimal swimming performance.

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Acknowledgments

I would like to thank the members of the High-Performance Training Center Victoria for volunteering to participate in the study. To Ryan and Brad thank you for being so willing to let me run my testing during the team's training schedule and being so accommodating to all the needs of my study. I would not have been able to even start this project if it wasn't for your support and desire to see me succeed.

Thanks to Liz Johnson for all of your help during the study and making sure that it ran smoothly. I greatly appreciate the time you put aside to answer any questions I had around exercise physiology and swimming. Your knowledge in the area was invaluable.

Thank you to Jake, Finn, Erica, Aimeson, Kathleen, Nestor, Jesse, Lorna and Conor for your help collecting data on the pool deck. Without your help the testing sessions wouldn't have run so smoothly, and I wouldn't have been able to do it without you.

Dr. Gaul, I greatly appreciate everything you did to help me complete this project, it made for a wonderful and relatively stress-free experience. Without your help I would not have been able to complete this project on such a tight timeline. I greatly value the time and effort you spent teaching me about exercise physiology, it has helped me develop into the student I am today, and I wouldn't be where I am without you.

Dr. Milford, your help with the statistical analysis was invaluable. I appreciated your willingness to meet with me whenever I needed and your guidance through the analysis process.

Thank you, Dr. Stuart-Hill, for your help with the data collection and sharing your knowledge around using the Jonah capsules and answering any questions I had around core temperature and my study.

Finally, I would like to thank my family and friends who have been with me every step of the way through this program. Your support means so much to me and I am grateful to have had you beside me throughout this whole experience.

Thank you.

1. Introduction

A warm-up is an integral part of sports performance and has been shown to improve subsequent athletic performance (Bishop, 2003a; Fradkin, Zazryn, & Smoliga, 2010; McGowan, Pyne, Thompson, & Rattray, 2015). With an improvement of 0.4% being the possible difference between winning a bronze medal and fourth place at the Olympics (Pyne, Trewin, & Hopkins, 2004), any improvements, even of the smallest of margins, could be the difference between being an Olympic medalist or being left off the podium. Swimmers at major international competitions tend to complete their initial pool warm-up up to 45 minutes before the start of an event without any additional warm-up during this transition time (McGowan, Pyne, Raglin, Thompson, & Rattray, 2016; Zochowski, Johnson, & Sleivert, 2007). This extended transition phase, the time between completion of warm-up and event, is due to the time it takes for swimmers to change into a racing swimsuit and the requirement to report to a marshalling ready room 20 minutes before the start of the race (FINA 2015). Based on previous research, it has been found that transition times that lasted longer than 20 minutes were detrimental to performance when compared to transition times of 10 and 15 minutes (Neiva, Marques, Barbosa, Izquierdo, Viana, & Marinho, 2017; West et al., 2013a; Zochowski et al., 2007). Research in other sports such as cycling and running have also shown that transition times of 10-15 minutes are better for athletic performance than extended transition times (Bishop, 2003; Faulkner et al., 2013; Ross & Leveritt, 2001). The decreases in performance are due to loss of neuromuscular activation and reductions in muscle temperature (Bishop, 2003a, 2003b; Faulkner et al., 2013; McGowan et al., 2015; West et

al., 2013b). A transition time of 5-20 minutes has been shown to maintain the physiological benefits from warm-up while providing enough time to recover (Bishop, 2003a; Dawson et al., 1997; Kilduff et al., 2008).

Swimming research offers many challenges due to the environment of the pool. Unlike other sports, the pool limits the use of many types of exercise testing equipment. Research has been conducted on various aspects of swimming warm-up; some studied the effects of various intensities and durations of in-pool warm-up (Neiva et al., 2015; Neiva, Marques, Barbosa, Izquierdo, Viana, Teixeira, et al., 2017; Neiva, Marques, Fernandes, et al., 2014; Neiva, Marques, Barbosa, Izquierdo, & Marinho, 2014), different lengths of transition time (Neiva, Marques, Barbosa, Izquierdo, Viana, & Marinho, 2017; West et al., 2013a; Zochowski et al., 2007), and the inclusion of dryland activation during the transition phase (McGowan et al., 2017; McGowan, Thompson, Pyne, Raglin, & Rattray, 2016). Maintenance of the benefits of in-pool warm-up is a challenge for all swimmers at major national and international competitions. When swimmers finish their in-pool warm-up their bodies are wet and exposed to ambient air which is colder than body temperature. This cool, wet environment can cause swimmers to cool down much faster than athletes competing in other non-aquatic sports. This environmentally-induced cool down coupled with the extended transition phase swimmers experience sets the stage for attenuating the effectiveness of the in-pool warm-up, potentially limiting performance.

Due to the detrimental effects of long transition times on swimming performance, McGowan et al. (2017; 2016) conducted several studies that looked at alleviating the loss of in-pool warm-up benefits by utilizing passive, active or a combination of both passive and active warm-ups. These studies were the first to address the issue of long transition

times at international swimming competitions with addition of dryland activation. Their results showed that the combination intervention resulted in the most significant improvements in performance followed by active and then passive warm-ups alone. They found that by including a dryland activation during the transition phase, swimmers were able to have improvements in performance by maintaining some of the benefits from their initial pool warm-up (McGowan et al., 2017; McGowan, Thompson, et al., 2016). Although the outcomes of these studies were positive, the methods used would not be practical for many athletes. The studies used specialized exercise equipment and heated clothing that are not accessible to all athletes. At major international competitions, athletes do not have access to exercise equipment in the ready room because it is a small staging area where only athletes in upcoming races are allowed to enter. The development of a dryland protocol that can be completed in the confines of a ready room could be greatly beneficial to a swimmer's performance.

Many physiological mechanisms are involved with improving athletic performance, with neuromuscular activation, elevated muscle temperature and elevated VO_2 considered the main contributors (Bishop, 2003a; McGowan et al., 2015). While elevated muscle temperature has been suggested as the primary mechanism for improving performance, the role of neuromuscular activation via post-activation potentiation can play a big role in improving performance (Bishop, 2003a; McGowan et al., 2015). Neuromuscular activation can improve muscle performance in both endurance and short bouts of athletic performance, by increasing maximal contractile force, shifting the force-velocity relationship and enhancing motor neuron activity (Hodgson, Docherty, & Robbins, 2005; McGowan et al., 2015; Sale, 2002).

The biggest challenge around maintaining the physiological benefits from the post pool warm-up during an extended transition time in swimming is the culture and education of athletes and coaches. A study conducted by McGowan (2016) found that high-performance swimming coaches in Australia, Great Britain and Canada still believed that the transition time of greater than 30 minutes is optimal for performance. This belief remains even though many studies have demonstrated that shorter transition times are more beneficial to swimming performance (Neiva, Marques, Barbosa, Izquierdo, Viana, & Marinho, 2017; West et al., 2013a; Zochowski et al., 2007). Previously, warm-up strategies were developed through trial and error, often based on coach and/or athlete experiences as opposed to scientific evidence (McGowan, Pyne, et al., 2016). It is important that coaches and athletes are well informed of the optimization of time between in-pool warm-up and competition, and what might be involved during this transition period that could help ensure best performance. It is vital that athletes find ways to minimize the post-warm-up decreases in heart rate and core and muscle temperature while waiting to compete, to maintain any physiological performance benefits from their initial warm-up.

1.1 Purpose

The purpose of this study was to determine if the inclusion of a dryland activation during the transition phase of a swimming competition would improve the performance of a 200-metre swimming time trial.

1.2 Research Questions

- 1) Does an additional dryland activation during the transition phase lead to improved performance?

- 2) Does an additional dryland activation elevate heart rate?
- 3) Does an additional dryland activation elevate T_{core} ?
- 4) Does an additional dryland activation provide neuromuscular activation?

1.3 Hypothesis

The present study tested the null hypothesis that the inclusion of a dryland activation during the transition phase would not significantly benefit swimming performance or cause any significant changes to the measured physiological variables.

1.4 Delimitations

The study was delimited to swimmers who had achieved a National qualification standard set out by Swimming Canada at the time of testing and who were currently training with the High-Performance Centre Victoria.

1.5 Limitations

The study environment simulated a competition setting with a simulated ready room. With the addition of a new protocol there may be a placebo effect that could have influenced performance either positively or negatively.

1.6 Assumptions

The participants were elite athletes, and all gave maximal effort during each testing session.

1.7 Operational Definitions

1) Transition Phase

The period between completion of in-pool warm-up and the start of the 200m time trial (McGowan, Thompson, et al., 2016).

2) Core Temperature (T_{core})

Internal body temperature, measured in °C using an ingestible capsule.

3) Heart Rate (HR)

Heart rate measured in beats per minute (BPM) (ACSM, 2014).

4) 200 Metre Time Trial (TT)

The time to 100th of a second for the athlete to complete 200 metres in their primary stroke.

2. Review of Literature

2.1 Introduction

The warm-up is an essential part of athletic performance. With a lack of empirical research in swimming, warm-up strategies were developed by athletes and coaches via trial and error to improve athletic performance. There is no one physiological mechanism from warm-up that is responsible for improving performance as there are different neurological, muscular and cellular mechanisms working together to achieve this. The primary mechanism that has been found to most greatly influence performance is an elevation of core and muscle temperature (Bishop, 2003a, 2003b). Mechanisms linked to improved performance include increased muscle metabolism (Gray et al., 2011), oxygen uptake (Burnley, Doust, & Jones, 2005), post-activation potentiation (PAP) and improvements in cardiovascular efficiency (Gerbino, Ward, & Whipp, 1996). Many new warm-up strategies have been developed in light of the new research, with both passive and active warm-ups being used to maintain or elevate core and muscle temperature. It has been found that increase of as little as 1°C in T_{muscle} can improve performance by up to 2-5% (Bergh & Ekblom, 1979; Racinais & Oksa, 2010; Sargeant, 1987). Recent research in swimming has shown that an additional active warm-up is more beneficial to improving performance than passive warm-up alone (McGowan et al., 2015).

2.2 Transition Phase Impact on Performance

Extended transition times during international swimming competitions are not avoidable due to a Federation International de Natation (FINA) mandated marshalling period (FINA, 2015) and the time it takes to don a swimmer's competition suit. Athletes tend to complete their pool warm-up upwards of 30 minutes before their race (McGowan, Pyne, et al., 2016; Zochowski et al., 2007). While both passive and active warm-up have

been shown to improve performance, active warm-up has been shown to have greater performance improvements (Bishop, 2003b; McGowan et al., 2017; McGowan, Thompson, et al., 2016).

Decreasing the transition time between warm-up and competition has been shown to improve 100m and 200m swimming performance (Neiva, Marques, Barbosa, Izquierdo, Viana, & Marinho, 2017; West et al., 2013a; Zochowski et al., 2007), while the use of a dryland activation during a transition phase has also been found to improve sprint swimming performance (McGowan et al., 2017; McGowan, Thompson, et al., 2016). The studies conducted by Zochowski et al., (2007); West et al., (2013); Neiva (2017) found significant improvements in swimming performance when a shorter transition time was employed. Zochowski et al., (2007) and West et al., (2013) found that by reducing the transition time from 45 minutes to 10 and 20 minutes 200m swimming performance improved by 1.4% and 1.5%, respectively. The study conducted by Neiva et al., (2017) reported an improvement of 1.12% in 100m swimming performance when the transition phase was reduced from 20 minutes to 10 minutes. While the reduction of transition times does not reflect a competition scenario due to the 20-minute marshalling period, the use of a dryland activation during the transition phase could help maintain the benefits from swimmers' initial pool warm-up. The studies conducted by Zochowski et al., (2007); West et al., (2013); and Neiva et al., (2017) all found that elevated HR and T_{core} due to the shorter transition phase were most likely the reasons for improving performance. Similarly, the studies by McGowan et al., (2016; 2017) which employed a dryland activation found that T_{core} was better maintained, and there may have been a "re-activation" which may have provided a neuromuscular activation. The studies conducted

by McGowan et al., (2016; 2017) required specialized equipment that not all athletes will have access to at a swimming competition: boxes for jumping, medicine balls and a body blade. If athletes do choose to use specialized equipment as a method of re-activation, the athletes would have to perform their activation before entering the marshalling area as athletes are not allowed to bring exercise equipment into the ready-room. Because of this, the re-activation would have to be completed up to 20 minutes before an athlete's race, which is enough time to lose some of the physiological benefits from the activation.

2.3 Temperature and Physical Performance

There is conflicting research on whether it is elevated muscle temperature itself or the method by which the muscle temperature is increased, that leads to improved performance. Both passive and active methods of elevating T_{muscle} have been shown to improve exercise performance, but it has been found that actively elevating muscle temperature leads to greater improvements in performance (Bishop, 2003a).

Temperature-related physiological mechanisms are regarded as the primary factors that are changed via warm-up and can lead to improvements in subsequent exercise performance. The first researchers to propose that elevated temperature could lead to improved performance were Asmussen and Boje in 1945. They believed that "higher temperatures facilitated the performance of work". Temperature-related mechanisms include increased metabolism within the muscle (Febbraio et al., 1996), improved muscle fibre function, and muscle fibre conduction velocity (Gray et al., 2011). It has been shown that as little as 1°C increase in T_{muscle} can improve performance by up to 2-5% (Bergh & Ekblom, 1979; Racinais & Oksa, 2010; Sargeant, 1987). In contrast to elevated T_{muscle} , low muscle temperature can slow-down chemical reactions in the muscle

(Oksa, Rintamäki, & Rissanen, 1996), cause delays to cross-bridge cycling (Asmussen, Bonde-Petersen, & Jørgensen, 1976), shift the force velocity curve leftward (De Ruiter & De Haan, 2000) and decrease the sensitivity of actomyosin to calcium (Hartshorne, Barns, Parker, & Fuchs, 1972).

2.3.1 Increased Muscle Metabolism

Muscle metabolism increases at higher temperatures and has been well known since 1975 (Fink, Costill, & Van Handel, 1975). More recently, research has shown that elevated T_{muscle} results in faster ATP turnover and creatinine phosphate utilization (Febbraio et al., 1996; Gray et al., 2011). Relationships have been found between increased anaerobic glycolysis and glycogenesis with elevated muscle temperature (Gray, Devito, & Nimmo, 2002; Gray, 2005). Increased levels of muscle glycogen breakdown are due to a combination elevated epinephrine and muscle temperature levels (Fink et al., 1975). The increases in ATP turnover and glycolysis can increase muscle power output. Gray (2011) discovered that with increased T_{muscle} the increased ATP turnover only lasted for the first 2 minutes of a 6 minute bout of high-intensity exercise. Febbraio et al., (1999) also found that there were increased levels of glycogenolysis, lactate production and NH_3 accumulation as muscle temperature increased. The changes reported in this study showed that there was a greater contribution from anaerobic glycolysis when T_{muscle} was elevated during 2 minutes of high intensity exercise on a cycle ergometer. The improvements to anaerobic metabolism and ATP turnover due to elevated T_{muscle} apply to short and middle-distance swimming races (< 2 minutes) and can help improve performance over these distances. T_{muscle} also has an influence on vasodilation and

oxymyoglobin dissociation which both allow for a greater oxygen availability at the working muscles (Barcroft & Edholm, 1943).

2.3.2 Muscle Fibre Performance

Elevated T_{muscle} has been shown to increase the maximal power output of Type II muscle fibre type at high velocities, while at low contractile speeds Type I fibre type see improvements (Gray, 2005; Gray, Söderlund, & Ferguson, 2008). Contractile velocity will influence what muscle fibre type benefits from increased T_{muscle} levels. At high-velocity, type II fibres will gain more from elevated T_{muscle} due to increased PCr and ATP utilization, while at low contractile velocity Type I muscle fibre types will see improvements. The ideal temperature range for peak power output is 26°C-37°C with higher temperatures associated with increased power output (de Ruiter, Jones, Sargeant, & de Haan, 1999). Because of the high-velocity contraction required for a swim start, greater T_{muscle} will improve start performance due to peak muscle contraction velocity being temperature dependent (McGowan et al., 2015). A relationship between T_{muscle} and muscle fibre cross-bridge cycling has been found (Gillis, 1985) leading to an increase in the production of force at higher muscle temperatures. The increase in cross-bridge cycling due to elevated T_{muscle} is believed to be due to improved rate of relaxation within cross-bridges during contraction (Segal, Faulkner, & White, 1986). Higher T_{muscle} improves calcium removal from the myoplasm and calcium-troponin dissociation which leads to cross-bridge detachment (De Ruiter & De Haan, 2000; Gillis, 1985).

2.3.3 Muscle Fibre Conduction Velocity

Gray (2008) found that a T_{muscle} increase of ~3°C has a significant increase in muscle fibre conduction velocity (MFCV) and power output by having individual

sarcomeres activated more rapidly. These increases will lead to improved changes in the force-velocity profile of muscles (Girard, Carbonnel, Candau, & Millet, 2009; West et al., 2016) The increases in MFCV could also be due to the higher T_{muscle} causing the voltage-gated Na^+ channels to open and close slower (Rutkove, 2001).

Elevated T_{muscle} has been shown to improve the speed at which nerve impulses travel (Karvonen, 1992; Ross & Leveritt, 2001). This can improve reaction time and the speed at which muscles will contract. This is important for events that have multiple complex body movements, as required in swimming (Bishop, 2003a).

Low T_{muscle} has been shown to negatively affect the force-velocity curve (De Ruiter & De Haan, 2000). The leftward shift of the force velocity curve due to low T_{muscle} has been found to affect dynamic exercise more than isometric contractions (Bergh & Ekblom, 1979). Cooler muscles contract at a slower velocity for a given force output compared to a muscle at elevated temperature (De Ruiter & De Haan, 2001). In studies conducted by Bergh & Ekblom (1979) and Sargeant, (1987), when legs were immersed in a cold bath jump performance and muscle power production were reduced, compared to when the legs were immersed in a hot bath.

2.3.4 T_{core} VS T_{muscle}

It has been shown that there are temperature differences between T_{core} and T_{muscle} during exercise (Bishop, 2003a; Kenny et al., 2003; Saltin & Gagge, 1968). The study conducted by Saltin et al., (1968) found that there can be up to a 0.7 °C difference between T_{muscle} compared to rectal temperature, while Kenny et al., (2003) found that deep T_{muscle} increased at a much faster rate than esophageal temperature (0.55°C/min vs

0.02°C/min) during exercise. These differences in rate of temperature increase will reach equilibrium within five minutes (Kenney et al., 2003).

2.3.5 Effect of Menstrual Cycle on T_{core}

It has been well documented that T_{core} changes throughout the menstrual cycle of women (Janse de Jonge, 2003). T_{core} can be elevated as much as 0.3 – 0.5 °C during the luteal phase of the menstrual cycle (Hessemer & Brück, 1985; Marshall, 1963). This increase in T_{core} has been linked to changes in hormone levels, specifically progesterone and estrogen, which are at their highest levels during the luteal phase (Farage, Neill, & MacLean, 2009).

2.4 Neuromuscular Mechanisms Impacting Physical Performance

Skeletal muscle contractile force can be affected by contractile history. A maximal voluntary contraction (MVC) or a short high intensity contraction improves subsequent muscle contractile performance through mechanisms associated with post-activation potentiation (PAP) (Hodgson et al., 2005). PAP leads to an increased rate of force development due to a reduction in time to reach peak force. This conditioning occurs via MVC or a high-intensity warm-up, which can improve sprint and power-based performance (Wilson et al., 2013). PAP functions by increasing the phosphorylation of the myosin light-chains and sensitivity to calcium. While there have been mixed results around the benefits of PAP in swimming most of those studies did not allow for adequate rest post MVC (Bishop, 2003b). While PAP has usually been performed using maximal weights such squats or bench press, benefits to vertical jump performance of up to 5% have been seen after performing drop jumps or weighted jumps (Tobin & Delahunt,

2014). Plyometric and ballistic exercises have also been shown to improve performance by 2 - 5% (Maloney et al., 2014; Seitz & Haff, 2015). These findings showed that athletes could benefit from PAP without requiring heavy resistance exercise. Recovery time for ballistic activation exercises prior to criterion performance has been found to range from 60s to 3min, which is much lower than required for heavy resistance exercise (Maloney et al., 2014). Recovery times have been shown to range between 4 minutes up to 18.5 minutes when using heavy resistance exercise (Chiu et al., 2003; Kilduff et al., 2008; Smith et al., 2014; Wilson et al., 2013).

Endurance trained athletes have also been shown to benefit from PAP (Hamada et al., 2000). PAP was found to only enhance the athlete's muscles that were most frequently trained. For example, triathletes had enhanced PAP in both upper and lower body muscles while runners had enhanced PAP responses in plantar flexors (Hamada et al., 2000). Endurance trained athletes tend to have enhanced fatigue resistance which can help elicit a PAP response (Hamada et al., 2000). PAP can also play a role in improving endurance exercise by helping delay fatigue. The delay in fatigue is caused by a compensating effect for low frequency force output and motor units firing at a lower rate for a given force output early during exercise due to potentiation (Hamada et al., 2000; Sale, 2002). When motor units fire at a lower rate it reduces the number of nerve impulses and action potentials generated which could, in turn, delay fatigue within the muscle during endurance exercise (Sale, 2002)

The difficulty with prescribing PAP activation is the inter-individual variability in responses. The response to PAP is dependent on resistance training background and sex (Chiu et al., 2003; Comyns, Harrison, Hennessy, & Jensen, 2006; Kilduff et al., 2011;

McCann & Flanagan, 2010; Wilson et al., 2013). Athletes require individualized exercises and recovery times to elicit the most benefit from PAP (Comyns et al., 2006; Wilson et al., 2013). Therefore, it is important to take into consideration all these factors when designing a protocol to get the full benefits of PAP.

Active warm-up can improve neuro-muscular function by cycling the actin-myosin bonds that are formed through muscle inactivity. Muscles that have been inactive have increased levels of actin-myosin bonds causing muscle stiffness (Enoka, 2002, p. 271-302).

2.5 Effect of Menstrual Cycle on Exercise

There has been conflicting research on whether menstrual cycle influences exercise performance (Janse de Jonge, 2003). Research has found that there are no negative effects of menstrual cycle phase on VO_{2max} , time to exhaustion and anaerobic performance (de Jonge, Boot, Thom, Ruell, & Thompson, 2001; Gür, 1997; Janse de Jonge, 2003; Lebrun, McKenzie, Prior, & Taunton, 1995). Research has found that there muscle contractile force may be increased during the follicular phase, at mid-cycle (day 12-18) due to elevated estrogen levels (Janse de Jonge, 2003; Phillips, Sanderson, Birch, Bruce, & Woledge, 1996). In contrast, it has also been reported that elevated estrogen levels could have negatively influence hand grip strength (Janse de Jonge, 2003). Some research has found that due to elevated T_{core} during the luteal phase, exercising in warm environments could negatively affect performance (Janse de Jonge, 2003)

2.6 Passive and Active Warm-up

There are two methods to elevating T_{muscle} and T_{core} before exercise, either through a passive or active warm-up. Passive warm-up uses an external heat source to elevate

temperature such as heat pads and heating garments, while active warm-up uses exercise to elevate temperature (Bishop, 2003). Both active and passive methods are used to maintain an already elevated temperature from an initial warm-up. It has been shown that a combination of both passive and active lead to greater improvements than either passive or active alone (McGowan et al., 2016). The importance of maintaining T_{muscle} and T_{core} has been shown in research conducted using passive warm-up strategies during transition phases (McGowan et al., 2015). In cycling, passive warm-up methods where T_{muscle} is maintained over a 30-minute transition phase has been shown to provide improvements to cycling power stroke (Karatzafiri, de Haan, van Mechelen, & Sargeant, 2001). The benefits of passive heat and its influence on performance have been varied, some studies have shown that passively increasing muscle temperature does not improve performance while some have shown improvements. Passive warm-up has been shown to improve both dynamic force and performance up to 5 minutes (Bergh et al., 1979, Bishop, 2003). Passively heating the muscle has also been found to improve the muscle fibre conduction velocity and power output (Gray et al., 2006). However, while passive warm-up techniques have been shown to help maintain T_{muscle} and T_{core} , it is an expensive method since heated garments are fairly expensive and not easily accessible to the majority of athletes competing.

Active warm-up strategies have been shown to increase T_{muscle} , T_{core} and can help reduce muscle stiffness and increase muscle fibre conduction velocity (Enoka, 2002, p. 271-302). Active warm-up leads to increases of up to 12% in MFCV (Girard et al., 2009). While mechanisms are yet to be explained for why there is improved MFCV after warm-up, some proposed mechanisms include; increased calcium release from

sarcoplasmic reticulum (Melzer, Herrmann-Frank, & Lüttgau, 1995), increased Na⁺/K⁺ pumping, muscle swelling (van der Hoeven, Van Weerden, & Zwarts, 1993) and increased activation (Gray et al., 2006). This is particularly important for sprint-based sports or power movements such as a swim start, as the rate of force development needs to be very high to achieve peak power as quickly as possible. Active warm-up also influences the acetyl-carnitine availability which could improve mitochondrial activity and reduce the reliance on anaerobic systems (Gray et al., 2002). The study conducted by Gray et al., (2002) found that an increase in acetyl-carnitine levels is linked with a reduction of blood and muscle lactate. Acetyl-carnitine can act as an extra substrate for oxidative ATP production (Greenhaff et al., 1994).

2.7 Cardiovascular Benefits from Warm-up

For events that are considered intermediate or long distance, or more than 2 minutes in duration, energy is generated through oxidative metabolism. A high-intensity aerobic warm-up can affect the VO₂ response to subsequent events (McGowan et al., 2015). High-intensity warm-up exercise increases the primary VO₂ response while reducing the slow O₂ kinetic component (Bailey, Vanhatalo, Wilkerson, DiMenna, & Jones, 2009). Starting a criterion performance with an elevated VO₂ has been shown to increase time to exhaustion by 15-30% (Bailey et al., 2009). Elevated VO₂ at the start of an event will also spare anaerobic stores, and decrease oxygen deficits which allows for an extra “kick” later in the event (Bishop, 2003a; Burnley et al., 2005; Gutin, 1973; McCutcheon et al., 1999).

There have been mixed results around high-intensity warm-up exercise influencing subsequent exercise performance (Koppo & Bouckaert, 2001; Wilkerson,

Koppo, Barstow, & Jones, 2004). McGowan (2015) believed that due to the highly intensive nature of the warm-up and lack of sufficient recovery time decreases in performance were reported in these studies. Because of the intense nature of the anaerobic warm-up, glycogen stores must be replenished sufficiently. It is also important that the warm-up be of sufficient intensity, if it is below lactate threshold it will not lead to improved exercise performance (Bailey et al., 2009). Another factor associated with high-intensity warm-up affecting O_2 kinetics is lactic acidosis (Bailey et al., 2009). By increasing blood lactate levels to over three mmol/L, there are improvements to O_2 kinetics (Bailey et al., 2009). It is well known that elevated VO_2 will help "spare" some anaerobic energy by lowering the O_2 deficit, other mechanisms such as O_2 kinetics, oxidative enzyme activity and oxygen uptake mechanics are less well researched. The mechanisms that are involved in improving the VO_2 response to exercise are increased primary VO_2 response while decreasing the VO_2 slow component and increased oxidative enzyme activity.

2.8 Limitations in Literature

The majority of warm-up research in swimming has looked only at 50m and 100m events. The vast majority of Olympic events are 200m and longer; of the fourteen individual Olympic events eight are over 200m. These events use different energy systems and would require different warm-up strategies than those of 50-100meter distances. It is not known exactly how the addition of transition phase warm-up would affect performance in these more extended events.

There is currently a lack of research on the performance of an active warm-up during the transition phase as a method to reduce the amount of time between warm-up

and the start of the event (McGowan et al., 2015). Previous studies did not have replicated a competition environment. Further, they have included specialized equipment that athletes do not have access to in the marshalling ready room. The study conducted by McGowan (2016; 2017) required medicine balls, body blade and elevated boxes for jumping. The need for specialized equipment limited the generalizability and applicability to real competitive conditions. They also had a variable time for athletes to perform the dry-land based warm-up (21 to 16 minutes before the event). Athletes completed the circuit 21 minutes before entering a simulated marshalling area and could have lost some of the benefits from the warm-up due to the longer recovery period. There have been some studies that reported improvements in swimming performance when the transition time was reduced to 10 or 20 minutes (Neiva, Marques, Barbosa, Izquierdo, Viana, & Marinho, 2017; West et al., 2013a; Zochowski et al., 2007) from 30 or 45 minutes. These studies are not generalizable to an international competitive environment due to the requirement for athletes to enter a marshalling ready-room 20 minutes before an event (FINA 2011).

2.9 Summary

In summary, elevating or maintaining T_{muscle} and T_{core} can improve exercise performance. Elevated levels of anaerobic and aerobic metabolism, ATP turnover and muscle fibre function seem to be the primary temperature-related mechanisms. PAP could also play a significant role in providing neuromuscular activation leading to improvements in both sprint and endurance performances.

It is important to note that swimmers who compete at major international competitions tend to have extended transition phases between warm-up and competition.

Because it has been shown that extended transition times between warm-up and competition could be detrimental to swimming performance (Neiva, Marques, Barbosa, Izquierdo, Viana, & Marinho, 2017; West et al., 2013a; Zochowski et al., 2007), it is important that athletes find ways to maximize their performance potential. Even the smallest of improvements can be the difference between fourth place and standing on the podium (Pyne et al., 2004). Because of this potentially small yet meaningful difference, it is essential that any potential method for improving performance be investigated. At present, the few studies that have looked at transition phase warm-up have shown potential to improve performance. However, due to their limited generalizability to a real international level competition scenario, it is necessary to continue examining new strategies that can successfully be applied to an elite level competitive environment.

3. Methods

3.1 Participants

Nine elite swimmers from the High-Performance Center Victoria who had achieved at least one national time standard within the past season were recruited for this study. Participants were both male (n=2) and female (n= 7) between the ages of 14-28 years. All participants were informed of the study rationale, objectives, and procedures before providing written informed consent. This study was approved by UVIC Human Research Ethics Board (see Appendix 1).

3.2 Experimental Design

A randomized crossover design was employed for this study. After signing an informed consent form (Appendix 2), the participants completed two or four testing sessions each separated by one week. Four participants completed only two testing sessions, one of each condition, while 5 completed two testing sessions of each condition.

The participants were randomly assigned to one of the two transition conditions in the first session: an active dryland transition phase (DL) or a passive traditional transition phase (TRAD). This assignment was used to balance the protocol sequence and minimize any effect of ordering. Testing sessions were separated by at least six days to ensure enough recovery between sessions. To reduce the effects of circadian rhythms on heart rate and core temperature all testing sessions were conducted at the same time of day. To limit the effect of the weekly training load, the head coach maintained each swimmer's training load as similar as possible each week as to not let it affect the TT performance. Athletes were required to attend ten in-pool training sessions per week, as part of their team training schedule.

3.3 Experimental Testing Procedure

All of the swimmers completed at least one testing session with each of the passive (TRAD) or active dryland (DL) transition phase interventions (Figure 2.1). The swimmers completed each of their time-trials in the same stroke, based on personal preference. One day before the first testing session all swimmers took part in an introductory session. During this session, the testing timeline was described, and the dryland testing condition explained to ensure each athlete was comfortable with all of the exercises they would be performing. During the week prior to the first testing session, the height, age and weight of all swimmers were collected. The female swimmers self-reported their menstrual status during the week prior to their first testing session. Swimmers were requested to maintain the same nutrition routine and abstain from caffeine for the 12 h before the testing session. Swimmers were given a temperature capsule (Jonah, Vital Sense, Mini Mitter) at their regularly scheduled morning practice to ingest, which allowed for seven hours between ingestion and the testing session. Upon arrival to the pool for the testing session, swimmers completed a standardized warm-up protocol prescribed by the head coach, followed by either a thirty-minute passive transition phase (TRAD) or thirty-minute transition phase that included a five-minute dryland warm-up (DL). Athletes were paired randomly, and each pair staggered their start time by 5 minutes to prevent any delay in the testing session. Time trial (TT) start time was staggered within the pair by twenty to thirty seconds to allow them to complete the time trial individually, which reduced any competition influencing their performance. T_{core} and HR were measured throughout both the warm-up and transition phases. As shown in Figure 2.2, the first ten minutes of the transition phase were used for the athletes change into their competition suit. Following that, the TRAD group remained

seated for twenty minutes in a simulated ready room environment on the pool deck while the DL group sat for ten minutes in the same ready room area after which they then performed a standard 5-minute dryland warm-up protocol in the same ready room area. The DL transition finished with five minutes of quiet sitting. All swimmers wore the official team tracksuit (jacket and pants) throughout the transition phase to standardize the effect such clothing would have on maintaining body heat. Immediately at the end of the thirty-minute transition phase, each athlete completed a 200-metre time trial (TT) in their primary 200m event.

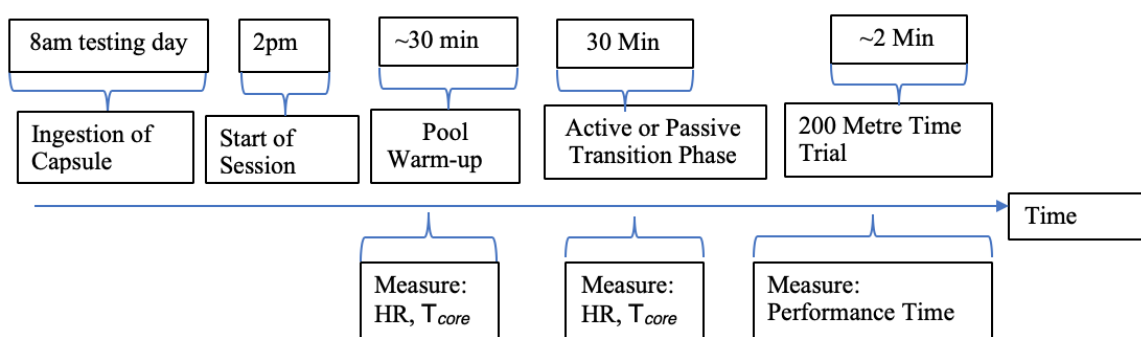


Figure 3.1 Time Course Events of Testing Session

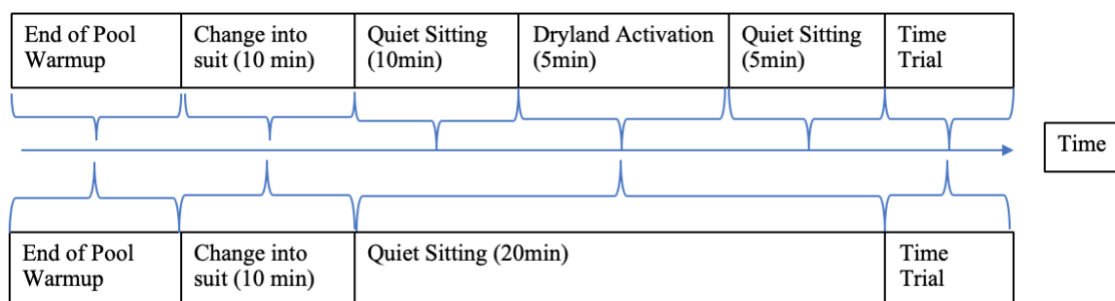


Figure 3.2 Transition Phase Time Course for both DL (top) and TRAD (bottom) Transition Phases

3.3.1 Pre-Time Trial Warm-up

Each athlete completed a standardized in-pool warm-up protocol, as directed by the head coach (Table 3.1). This standardized warm-up was maintained for all testing sessions to ensure consistency between trials.

Table 3.1 Standardized Warm-up Protocol

<u>Distance</u>	<u>Description</u>	<u>Interval</u>
400m	2 x [100m (50mSwim/50mDrill) 100m(Swim/Kick)] Fins	
3x100m	Legs only Kick: Descending 1-3	1:50
2x50m	Legs only Kick: 1 Build speed & 1 (25 fast/25 easy)	1:00
3x100m	Arms only Pull: Descending 1-3	1:40
2x50m	Arms only Pull: 1 Build speed & 1 (25 fast/25 easy)	1:00
4x50m	Freestyle: Descending 1-4	1:00
1x15m	Dive Max Effort	

3.3.2 Dryland Transition Phase Warm-up (DL)

The dryland transition phase included a five-minute dryland warm-up (Appendix 3A). The swimmers were allowed to take as much rest as they wished but were required to complete two rounds of the activation protocol within the allotted five minutes. Each round consisted of:

- 40 seconds of Jumping Jacks,
- 6 explosive burpees with explosive push up and squat jump

Completion of the DL protocol was monitored by the researcher. All of the athletes were very well accustomed to these exercises, as they perform them on a daily basis within their normal training protocols.

3.3.3 200 Metre Time Trial (TT)

After the 30-minute transition phase, each swimmer completed a TT in their primary stroke. Each athlete completed the TT individually. This was to reduce the effect “racing” could have had on the time trial result. Participants were directed to give a maximal effort similar to a competitive race.

The TT was filmed using a Canon HF-R800 video camera positioned to face the starting blocks from which all time trials were started. In addition, all TTs were timed by the same two coaches using Seiko S141 stopwatches (Appendix 3B). Video from the TT was used to confirm the coach-measured times. Individual TT performance times from the video were measured from when the athlete's feet left the blocks to when they touched the wall after completing 200 metres.

Due to technical difficulties with the video from the first testing session, all TT performance times are reported from a Seiko stopwatch used by the same two coaches for all TT. The video from the last three testing sessions were used to confirm the accuracy of the coaches' hand-held stopwatch times. As there was no significant difference between the coaches' stopwatch times and the time measured from the videos of all TT (mean difference: $0.03 \pm 0.10s$, $p > 0.001$), the coaches' stopwatch times were deemed highly accurate. All TT performance times reported are of those taken by the coaches.

3.4 Physiological Measurements

3.4.1 Core Temperature

Core temperature [T_{core}] was monitored throughout the entire testing session using an ingestible, biocompatible capsule (Jonah, VitalSense, Mini Mitter). The sensor uses radio frequency to transmit a data signal to a nearby monitor that displayed T_{core} (Appendix 3B). This telemetric core temperature measuring system has been validated

against rectal probe temperature and no significant differences were found (McKenzie & Osgood, 2004).

3.4.2 Heart Rate

For all testing sessions, each swimmer wore a Polar heart rate monitor (Polar OH1 Heart Rate Monitor, Polar Electro Inc.; Appendix 3B) on their upper arm. The position of the device was consistent with what occurs at all regular training sessions that each athlete performs with their coach and team. HR was monitored continuously throughout the entire testing session. The Polar OH1 HR monitor has been validated against an ECG HR monitor, with no significant differences found between methods (Horton, Stergiou, Fung, & Katz, 2017).

3.5 Statistical Analysis

The statistical analysis of the data was conducted using the SPSS software (version 24, IBM Inc.) with significance set at $p \leq 0.05$. Descriptive data were analyzed including means and standard deviations. Paired sample T-Tests were used to test for differences in transition protocols on time trial and physiological measures. Cohen's (1988) effect size guidelines of 0.2 represents a small effect size, 0.5 represents a medium effect size and 0.8 a large effect size were used. Due to the low participant numbers, and assumptions of a paired sample t-test, data were run through a bootstrap procedure following the initial data analyses (Efron & Tibshirani, 1986). Data are described as mean \pm SD.

4. Results

The original research design was to have all 9 athletes complete 4 testing sessions, 2 sessions of each transition phase condition. Due to scheduling conflicts, 4 of the swimmers were only able complete 2 of the testing sessions. The following results represent the first testing session of each condition that all 9 athletes completed.

4.1 Participant Physical Characteristics

A total of 9 swimmers completed one of each of the transition warm-up protocols.

The physical characteristics of each swimmer in this study are provided in Table 4.1.

Table 4.1 Physical Characteristics of Swimmers

<u>Subject</u>	<u>Sex</u>	<u>Age(yrs)</u>	<u>Height (cm)</u>	<u>Weight (kg)</u>
1	F	29	179.8	70.3
2	F	17	172.6	58.1
3	F	17	162.5	55.5
4	F	17	162.3	54.6
5	F	17	171.4	58.2
6	F	20	170.2	62.5
7	F	14	175.7	56.8
8	M	17	178.6	67.3
9	M	20	180.0	75.0
Mean		18.7	171.7	62.0
SD		4.3	6.6	7.2

4.2 Menstrual Cycle Status of Female Participants

All of the female athletes were eumenorrheic and completed their testing sessions either in the follicular or luteal phase of their menstrual cycle, based on self-report. During their first testing session four of the female swimmers were in the follicular phase and three were in the luteal phase. During their second testing session, all 7 of the female swimmers were in the luteal phase of their menstrual cycle.

4.3 Environment

The mean ambient air temperature on the pool deck was $25.1 \pm .4^{\circ}\text{C}$ and the relative humidity was 42.6% during both testing sessions. One swimmer completed their second testing session on the third day where the ambient air temperature was 26.8°C and relative humidity was 48.1%.

4.4 Heart Rate

As shown in Table 4.2 there are no significant differences in HR between DL and TRAD before and immediately following the pool warm-up. The combined group data showed that pool warm-up caused heart rate to significantly increase ($M = 105 \pm 16$ bpm to 136 ± 11 bpm), ($t(17) = 5.76, p < .001, \text{BCa } 95\% \text{ CI } [19.15, 41.30], d = (2.25)$). Heart rate also showed a significant decline of 47 bpm over the first twenty minutes in the combined group data ($t(17) = 14.15, p < .001, \text{BCa } 95\% \text{ CI } [39.62, 53.60], d = (3.9)$). Twenty minutes into the transition phase, heart rate was significantly higher in DL than in TRAD, ($t(8) = 2.35, p < .047, \text{BCa } 95\% \text{ CI } [0.17, 20.06], d = (.86)$). The dryland activation significantly elevated heart rate, ($t(8) = -5.90, p < .001, (\text{BCa } 95\% \text{ CI } [24.16, 55.17], d = (2.21))$) and heart rate was significantly higher after the dryland activation than at the same time in TRAD, ($t(8) = 6.41, p < .001, \text{BCa } 95\% \text{ CI } [31.88, 67.68], d =$

(2.76)). By the time the 30-minute transition phase ended, there was no difference in HR between the DL and TRAD conditions. All of the differences in HR represented a large effect size.

Table 4.2 Mean Heart rates (\pm SD) through the testing session (n=9)

	<u>Transition Phase Condition</u>	
	Dryland	Traditional
Pre-Pool Warm Up (bpm)	104 \pm 16*	103 \pm 14*
Post Pool Warm up (bpm)	136 \pm 11	136 \pm 11
20 minutes (bpm)	94 \pm 13* ⁺	84 \pm 10*
25 minutes (bpm) (Post Dryland)	134 \pm 22* ⁺	84 \pm 13*
Pre-Time Trial (bpm)	113 \pm 7*	112 \pm 14*

* significantly different from post-pool warm-up within the condition, $p > 0.05$

+ significantly higher than the Traditional transition at same time point, $p > 0.05$

4.5 Core Temperature

As provided in Table 4.3, there were no significant differences between DL and TRAD in T_{core} at any time. There was a significant increase in core temperature after the pool warm-up when the data from the two phases were combined, ($t(17) = -8.25$, $p < .001$, BCa 95% CI [0.39, 0.65], $d = (1.73)$). T_{core} significantly declined throughout the entire thirty-minute transition phase in the combined group data, ($t(17) = 5.28$, $p < .001$, BCa 95% CI [0.44, 1.02], $d = (1.53)$). T_{core} significantly declined in DL from the end of the pool warm-up to pre-TT in the combined group data, ($t(8) = 6.30$, $p < .001$, BCa 95% CI [0.23, 1.05], $d = (1.59)$). Similarly, T_{core} also significantly declined in TRAD from the

end of the pool warm-up to pre TT, ($t(8) = 4.16$, $p < .003$, BCa 95% CI [0.32, 1.37], $d = (1.54)$). All the differences in T_{core} represented large effect sizes.

Table 4.3 Mean Core Temperature (\pm SD) through the testing session (n=9)

	<u>Transition Phase Conditions</u>	
	Dryland	Traditional
Pre-Pool Warm Up (°C)	37.55 \pm .32	37.62 \pm .31
Post Pool Warm up (°C)	38.18 \pm .29*	38.13 \pm .30*
20 minutes (°C)	37.62 \pm .41	37.46 \pm .38
25 minutes (°C) (Post Dryland)	37.53 \pm .47	37.39 \pm .49
Pre Time-Trial (°C)	37.54 \pm .49	37.30 \pm .70

* Significantly higher than all other times within the condition, $p > 0.05$

4.6 200 metre Time Trial Performance

Table 4.4 provides the mean 200m time trial performance results for both the DL and TRAD conditions. All TT performances were better following the DL compared to TRAD, with mean times significantly faster following DL than TRAD, ($t(8) = -3.35$, $p < .010$, BCa 95% CI [0.34, 1.86], $d = (.11)$). When time trial data were examined more closely, the mean 50 metre split time at 150 meters following DL was significantly faster than TRAD ($t(8) = 2.97$, $p < .018$, BCa 95% CI [0.14, 1.12], $d = (.15)$). Differences in performance times represented a small effect size.

Table 4.4 Mean 200 metre time trial and split times (\pm SD) for both DL and TRAD (n=9)

	<u>Transition Phase Condition</u>	
	Dryland	Traditional
200m Time (secs)	130.61 \pm 10.46*	131.71 \pm 11.07
1 st 50m (secs)	29.72 \pm 2.34	29.77 \pm 2.13
2 nd 50m (secs)	33.32 \pm 2.34	33.71 \pm 2.13
3 rd 50m (secs)	34.83 \pm 4.28*	35.47 \pm 4.47
4 th 50m (secs)	32.66 \pm 1.94	32.73 \pm 1.87

* Significantly faster than the traditional transition phase time, $p > 0.05$

4.7 Bootstrapped Data

Due to the low participant numbers, and assumptions of a paired sample t-test, a post hoc bootstrap procedure was applied to the data (Efron & Tibshirani, 1986). A more detailed description of the bootstrapped data results can be found in Appendix 4. The bootstrapped data analysis found that the differences in HR remained significant. Differences in pre-warm-up and post warm-up T_{core} remained significant, as did the differences in post pool warm-up and pre-TT. The 200 metre and third 50 metre split differences between the two transition phases remained.

5. Discussion

The purpose of this study was to determine if the addition of a dryland activation during the transition phase of a swimming competition would improve 200 metre swimming performance in elite swimmers. The goal of the dryland activation was to maintain the benefits from the initial pool warm-up over a thirty-minute transition phase typically experienced at international level competitions. The results demonstrated that the DL allowed the swimmers to elevate their heart rate and provided some activation, after sitting for twenty minutes, before performing a 200m time trial. This modification to the transition phase helped break up the amount of time the athletes were seated and not moving. The inclusion of a dryland activation led to an improvement in 200m swimming performance, with 7 of the swimmers performing better and 2 of the swimmers swimming the exact same time. The results from the present study add to the current body of research of pre-competition swimming warm-up that includes an additional warm-up to improve competitive swimming performance in elite swimmers.

5.1 Transition Phase

Decreasing the transition time between warm-up and competition has been shown to improve 100m and 200m swimming performance (Neiva, Marques, Barbosa, Izquierdo, Viana, & Marinho, 2017; West et al., 2013a; Zochowski et al., 2007). The use of additional dryland exercises during a transition phase has also been found to improve sprint swimming performance (McGowan et al., 2017; McGowan, Thompson, et al., 2016). The present study included a 5-minute dryland activation five minutes prior to a 200m time trial in an attempt to break up the long transition phase typically experienced at international competitions and provide a re-warm-up for the athletes prior to their time

trial. The DL exercises were selected so they could be completed within the confines of the ready-room at international competitions and required no specialized exercise equipment. By choosing exercises that required no equipment, athletes were able to perform the dryland warm-up closer to the time of their race. Previous studies that explored the use of dryland exercises as a re-warm-up method required specialized equipment typically unavailable to swimmers in the ready room setting (McGowan et al., 2017; McGowan, Thompson, et al., 2016). These dryland exercises required boxes for jumping, medicine balls and a body blade, and the selected exercises were performed 16- to 20 minutes prior to the time trial. Further, the recovery period used in these studies were not ideal for performance, as it has been shown that the physiological benefits from PAP and warm-up start to dissipate within 5-12 minutes (Bishop, 2003a, 2003b; McGowan et al., 2015).

The exercises selected in the present study were chosen in consultation with the strength and conditioning coach at the High-Performance Center Victoria. Jumping jacks were chosen as they could elicit an increase in heart rate and core temperature as well as provide both upper and lower body mobility after being seated for twenty minutes. The burpees were selected as they included explosive movements for both upper and lower body limbs. The exercises selected in this study were also chosen for familiarity and relevance to the physical requirements of swimming. As swimming involves dynamic upper and lower limb movements, jumping-jacks warm-up and improve the mobility of all limbs while the burpees include explosive leg movements similar to the start off the blocks and push off the wall during turns, and activation of the upper body muscles consistent with swimming. The swimmers involved in this study performed these

exercises on a daily basis as part of their training program. The post dryland recovery time was set at 5 minutes as previous research has reported that a recovery time of greater than 5-minutes, but less than 12-minutes, provides the most benefit to subsequent performance (Bishop, 2003a, 2003b). The current research suggests that there was sufficient time to recover after the dryland activation as DL HR returned to the same value as in the TRAD condition pre-TT. The recovery of HR post dryland activation and improvement in TT performance over that measured post TRAD provide evidence that there was sufficient time to recover from the dryland activation while still maintaining the benefits of warming up.

5.2 Performance Time

The present study found a 0.84% improvement in mean TT performance with the inclusion of a five-minute dryland activation during a thirty-minute transition phase following a standard pool swimming warm-up. While 2 of the swimmers swam the exact same TT time, the 7 other swimmers improved their TT performance following DL. It is notable that no swimmer performed better following the TRAD protocol. Individual swimmer's improvement in TT performance following the DL ranged from .00s to 1.3s with a significantly faster mean third 50m split time. As this is the first study to explore performance benefits over 200m following a dryland activation, we are unable to compare the findings directly to previous studies. However, despite differences in exercise selection, post warm-up recovery time and time trial distance this research study found similar results to the studies conducted by McGowan et al., (2017; 2016) who reported a mean improvement of 0.7% in sprint swimming performance (100m), with the inclusion of a dryland warm-up during the transition phase.

The present study found performance improvements similar to studies conducted by West et al., (2013) and Zochowski et al. (2007) who reported that shorter transition phases of twenty- or ten-minutes compared to 45 minutes, improved 200m swimming performance by 1.5% and 1.4% respectively. The methods applied in the studies by West et al., (2013) and Zochowski et al., (2007) are not translatable to international competition due to the required 15 - 20 minute marshalling time that athletes must adhere to (FINA 2015) and the extended time athletes need to put on their competition racing suit (McGowan, Pyne, et al., 2016). These two factors alone can extend the transition time to around 45 minutes (McGowan, Pyne, et al., 2016; West et al., 2013a; Zochowski et al., 2007). Although the current study did not see as large of an improvement in performance as that reported by these shortened transition time studies, the inclusion of a dryland activation during the transition phase could be a more practical solution than decreasing the transition time at major international competitions, where athletes have little control over the length of the transition time.

As can be seen in Table 5.1, an improvement of 0.84% in the 4th place times for 200m events at the 2016 Olympic Games would have improved all but one Olympian's final placing. Outside of the Men's 200 metre backstroke, all of the fourth-place swimmers could have earned an Olympic medal, while three of the fourth-place swimmers could have earned a gold medal.

Table 5.1 Predicted Rio Olympic Placing Improvement from 4th Place using DL**Intervention**

Event	4th Place Time (s)	.84% improvement in time (s)	Predicted Final time	Final placing of predicted time
M 200 Freestyle	105.49	0.89	104.60	Gold Medal
M 200 Backstroke	115.16	0.97	114.19	4 th Place
M 200 Breaststroke	127.78	1.07	126.71	Gold Medal
M 200 Butterfly	114.06	0.96	113.10	Gold Medal
M 200 Individual Medley	117.54	0.99	116.22	Silver Medal
W 200 Freestyle	115.18	0.97	114.21	Bronze Medal
W 200 Backstroke	127.89	1.07	126.82	Bronze Medal
W 200 Breaststroke	142.34	1.20	141.14	Silver Medal
W 200 Butterfly	125.90	1.06	124.84	Silver Medal
W 200 Individual Medley	129.21	1.09	128.12	Silver Medal

5.3 Heart Rate

Heart rate increased significantly during the pool warm-up in both conditions.

This is consistent with previous research (Neiva, Marques, Barbosa, Izquierdo, Viana, &

Marinho, 2017; West et al., 2013a), which reported increased in HR post pool warm-up. There were significant differences in HR at the 20-minute period of the transition phase between DL and TRAD. It is certainly possible that the difference of 10 BPM could have been due to a natural anticipatory HR response to the impending novel DL exercise. Again, as to be expected, the heart rates of the swimmers were significantly higher following the dryland activation compared to the same time within the traditional transition phase. These results were similar to the ones reported by McGowan et al., (2017; 2016) who found increases in heart rate post dryland activation of 20-30 BPM. An even greater increase (50 BPM) was observed in the present study which could be due to the inclusion of two sets of forty seconds of jumping jacks, while the dryland warm-up conducted in the studies by McGowan et al., (2017; 2016) consisted of short bursts of explosive exercises (2 sets with 10s rest between exercises of 3 x 10 medicine ball slams, 3 x 10s simulated butterfly kick with body blade and 3 x 0.4m box jumps). With this increase in heart rate during the latter part of the transition phase, five minutes before the 200m time trial, athletes could have started the time trial at an elevated VO_2 which could have spared the athlete's anaerobic capacity for later in the 200m time trial (Jones & Lees, 2003). Previous studies have also shown that there are decreased oxygen deficits and an increased aerobic contribution when an active warm-up is performed before a bout of maximal exercise (Gutin, 1973; McCutcheon, Geor, & Hinchcliff, 1999). In the present study, while there was a significant increase in HR following the dryland activation there was also sufficient time to recover as HR returned to the same rate as TRAD pre-TT. With the return of HR to similar levels of the TRAD condition, it shows that the dryland activation did not induce long term fatigue. This return of HR paired

with the improvements in TT performance in DL compared with TRAD indicates that the 5-minute recovery period was sufficient for the swimmers to recover from the dryland activation.

5.4 Core Temperature

The present study saw no significant difference in T_{core} response between the two transition phase conditions at any point throughout the testing session. T_{core} significantly increased during the pool warm-up prior to each transition period condition. The mean increases in T_{core} of 0.53°C is similar to studies conducted by West et al., (2013) and McGowan et al., (2017; 2016), who found increases in T_{core} of 0.8°C and 0.7°C , respectively. All subjects consistently demonstrated a decrease in T_{core} over the first 20 minutes of the transition phase. The mean decrease of 0.32°C is consistent with results from a study conducted by West et al., (2013) where a 20-minute post pool warm-up transition phase caused a decrease of 0.3°C in T_{core} in elite level male and female swimmers. While there were no significant differences in T_{core} between transition phase conditions, the present study found that T_{core} decreased less in DL than in TRAD (-0.64 ± 0.32 vs. -0.84 ± 0.63). The difference in T_{core} immediately pre-TT approached significance ($p = 0.06$). These results are similar the findings of McGowan et al., (2017; 2016) who reported a decrease in T_{core} during all transition phase conditions but that this decrease was attenuated when a dryland activation was included in the transition phase ($-0.24 \pm 0.13^{\circ}\text{C}$ vs $-0.64. \pm 0.16^{\circ}\text{C}$). After the dryland activation in DL T_{core} did not decline, while T_{core} in the TRAD condition continued to decline until the end of the transition phase. The dryland activation may have acted in a protective manner to

prevent the core and muscles from cooling which has been shown to be detrimental to performance (Sargeant, 1987).

Previous studies have reported that elevated muscle temperature (T_{muscle}) plays a role in improving performance through various physiological mechanisms such as improved muscle metabolism, increased motor unit conduction velocity, and improved vasodilation (Bergh & Ekblom, 1979; Febbraio, Carey, Snow, Stathis, & Hargreaves, 1996; Ferguson et al., 2006; S. Gray & Nimmo, 2001; S. R. Gray, Soderlund, Watson, & Ferguson, 2011; Mohr, Krstrup, Nybo, Nielsen, & Bangsbo, 2004; Racinais & Oksa, 2010; Starkie, Hargreaves, Lambert, Proietto, & Febbraio, 1999). Although the present study did not measure T_{muscle} , as it is invasive and not practical in a pool setting, it is possible that the dryland activation may have had an effect on increasing T_{muscle} . During exercise, T_{muscle} has been shown to increase at a much faster rate than core temperature, and that within three to five minutes will exceed core temperature (Bishop, 2003a). Kenny et al., (2003), found that deep muscle temperature increases at a much faster rate than esophageal temperature from rest ($0.55^{\circ}\text{C}/\text{min}$ vs $0.02^{\circ}\text{C}/\text{min}$, respectively). With these previous findings considered, one could postulate that since the dryland activation of the present study lasted only five minutes, there could have been an increase in T_{muscle} without any significant change in T_{core} .

5.5 Neuromuscular Activation

Neuromuscular activation via post activation potentiation (PAP) has been shown to improve performance through two main mechanisms, enhanced motor unit excitability and increased phosphorylation of the myosin light chain (Hodgson et al., 2005).

Plyometric and ballistic exercises, such as the burpees used in the dryland activation,

have been shown to induce PAP (Maloney, Turner, & Fletcher, 2014; Turner, Bellhouse, Kilduff, & Russell, 2015). Ballistic exercises, exercises completed with the intention to move the body at maximal velocity (Desmedt & Godaux, 1977), have been reported to improve subsequent exercise performance by as much as 2-5% (Maloney et al., 2014). This method of inducing PAP was used for the current study, as the objective was to elicit neuromuscular activation without the use of any specialized exercise equipment. Although not measured, it is very possible that the significant TT performance improvements in the current study were due to neuromuscular activation from the dryland activation, specifically through PAP. It has been shown that neuromuscular activation via PAP can improve short explosive movements on land, such as with vertical jumps (Tobin & Delahunt, 2014). However, a number of studies (Abbes et al., 2018; Kilduff et al., 2011; Sarramian, Turner, & Greenhalgh, 2015) have found that a PAP activation protocol had no effect on swimming start or sprint performance. In contrast, Cuenca-Fernández, López-Contreras, & Arellano (2015), reported improved swimming start performance while, Hancock et al., (2015) reported an improvement of 0.54s in 100m swimming time by performing a neural muscular activation to induce PAP swimming. The lack of measurable benefit from the dryland activation over the first 50m in the present study could have been due to the activation load not being sufficient to stimulate a PAP response.

In addition to helping short explosive movements, it has been proposed that PAP could enhance endurance performance (Hamada, Sale, & Macdougall, 2000; Sale, 2002). During submaximal contractions motor units fire at lower rates without any decrease in motor unit recruitment (de Luca, Foley, & Erim, 1996). When potentiation is developing

early on during exercise, motor units fire at a lower rate for a given force output due to the potentiation, which shifts the force-frequency relation leftward (Hamada et al., 2000). This could lead to a "saving" effect of the central motor drive (Hamada et al., 2000). PAP could also have the ability to delay fatigue by compensating for the low frequency force output during exercise (Hamada et al., 2000; Sale, 2002). Although not measured in this study, it could be why there was no significant difference between the conditions over the 1st 100m of the time trial but that in the 3rd 50m split (between 100-150m) the swimmers swam faster after DL than the TRAD. The athletes could have had a similar force output at the beginning of the post DL time trial, compared to the TRAD, while motor units fired at a lower rate, which could have helped improve performance during the second half of the time trial.

It is also important to consider that PAP has been shown to have very individualized results and can be dependent on the athlete's resistance training status (Chiu et al., 2003; McCann & Flanagan, 2010; Wilson et al., 2013). The current study found a range of 0.00s to 2.94s improvement in TT performance. Because of this large range in performance improvements, swimmers could have had different neuromuscular responses to the dryland activation as not all the swimmers in the study were on the same resistance training program. Similarly, studies have reported mixed results on the amount of post-PAP recovery time for optimal performance. Recovery times as short as 4 minutes and upwards of 8-18 minutes have led to improved performance (Chiu et al., 2003; Kilduff et al., 2008; Smith et al., 2014; Wilson et al., 2013). The present study selected a post dryland activation recovery time of five minutes to reduce as much time between activation and warm-up, within the time confines of a typical international

competition transition time. While it is on the lower end of reported effective recovery times, it has been shown that recovery times of four minutes still produced improvements via PAP (Kilduff et al., 2011; Nibali, Chapman, Robergs, & Drinkwater, 2015; Wilson et al., 2013). With the improvements in TT performance, the results suggest that there was enough time to recover from the dryland activation while still maintaining some level of neuromuscular priming from the explosive exercises.

5.6 Limitations

There are a few limitations to this study that must be considered when interpreting the findings. There is a possibility that a placebo effect was present as it was not possible to blind the participants from the dryland activation. The participants were made aware of the study purpose and it may have played a role in influencing performance. While the athletes were previously made aware of the performance benefits from reducing the transition time and re-warm-up, the majority of the swimmers do not currently engage in additional activation during the transition phase during competition. The inclusion of a new protocol could have influenced their performance positively or negatively depending on their willingness to adapt to a new protocol or their willingness to include a novel warm-up protocol to their pre-race routine.

As the majority of the swimmers were female (n=7) menstrual status could have influenced TT performance and T_{core} measurement. During the first testing session four of the female swimmers were in the follicular phase while three were in the luteal phase of their menstrual cycle. As the female swimmers were in different phases of their menstrual cycle during the first testing session this could have had an influence on T_{core} measurements or performance. Although the research is conflicted on the effect

menstrual cycle has on exercise performance, it is unlikely that it played a role in influencing TT performance. However, menstrual cycle phase could have influence T_{core} as it is well known that T_{core} is elevated during the luteal phase (Marshall, 1963).

Elite swimmers were difficult to recruit due to the limiting nature of “elite” classification and their busy training and competition schedules. Due to the small sample size there is increased the likelihood of Type II error which affected the power of the study. As not all the athletes were able to attend all four testing sessions, analysis of the results from only one testing session of each condition was conducted. By only including one testing session of each condition the repeatability of the results was not investigated.

5.7 Future Research

Future research should include measurements of T_{muscle} , and start and stroke parameters (reaction time, time to 15m, stroke rate, stroke length). As T_{muscle} plays such an important role in improving performance, measurements of T_{muscle} would allow for a better understanding how the dryland activation influenced T_{muscle} and performance. It could provide a greater understanding of the variations than can occur between T_{core} and T_{muscle} during the transition phase. Additionally, the measurements of start time and stroke parameters could provide more detail into how exactly the dryland activation influenced swimming performance. Finally, due to the individual nature of PAP a wider range of priming exercises should be explored with athletes individually to find the best exercises to elicit the most PAP benefits.

5.8 Conclusion

The current research examined the effect of a dryland activation during the transition phase. The study found that the inclusion of a dryland activation 5 minutes

prior to a 200m TT improved swimming performance over the traditional transition phase where the athletes sat quietly for 20 minutes, with a significant improvement in third 50m split. While there were no significant differences in T_{core} between the conditions, the DL condition provided better maintenance of T_{core} through the transition phase. The dryland activation also elicited a significant increase in HR which could have provided a re-warm-up which might have positively influenced performance.

In conclusion, the research in the present study supports the inclusion of a dryland activation during the transition phase of competition swimming. It appears to maintain some of the physiological benefits from the in-pool warm-up and might even enhance the warm up effect leading to enhanced performance. Due to the current culture in swimming, this research could help educate coaches and athletes on how to optimize extended transition times at major competitions.

6. References

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7. Appendix

Appendix 1. Human Research Ethics Board

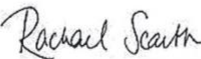


University
of Victoria

Office of Research Services | Human Research Ethics Board
Michael Williams Building Rm B202 PO Box 1700 STN CSC Victoria BC V8W 2Y2 Canada
250-472-4545 | 250-721-8960 | uvic.ca/research | ethics@uvic.ca

SCANNED

Certificate of Approval

PRINCIPAL INVESTIGATOR: Jeremy Bagshaw	ETHICS PROTOCOL NUMBER: 18-260 Minimal Risk Review - Delegated
UVic STATUS: Master's Student	ORIGINAL APPROVAL DATE: 13-Sep-18
UVic DEPARTMENT: EPHE	APPROVED ON: 13-Sep-18
SUPERVISOR: Dr. Kathy Gaul	APPROVAL EXPIRY DATE: 12-Sep-19
PROJECT TITLE The Effects of a Secondary Dryland Activation on Swimming Performance	
RESEARCH TEAM MEMBERS Dr. Lynne Stuart-Hill (Committee Member, UVic); Elizabeth Johnson (Researcher, Canadian Sports Institute)	
DECLARED PROJECT FUNDING: None	
CONDITIONS OF APPROVAL	
This Certificate of Approval is valid for the above term provided there is no change in the protocol.	
<p>Modifications To make any changes to the approved research procedures in your study, please submit a "Request for Modification" form. You must receive ethics approval before proceeding with your modified protocol.</p> <p>Renewals Your ethics approval must be current for the period during which you are recruiting participants or collecting data. To renew your protocol, please submit a "Request for Renewal" form before the expiry date on your certificate. You will be sent an emailed reminder prompting you to renew your protocol about six weeks before your expiry date.</p> <p>Project Closures When you have completed all data collection activities and will have no further contact with participants, please notify the Human Research Ethics Board by submitting a "Notice of Project Completion" form.</p>	
Certification	
This certifies that the UVic Human Research Ethics Board has examined this research protocol and concluded that, in all respects, the proposed research meets the appropriate standards of ethics as outlined by the University of Victoria Research Regulations Involving Human Participants.	
 <hr/> <p>Dr. Rachael Scarth Associate Vice-President Research Operations</p>	

Certificate Issued On: 13-Sep-18

18-260
Bagshaw, Jeremy

Appendix 2 Consent Form



University
of Victoria

School of Exercise Science,
Physical & Health Education

The Effects of a Secondary Dryland Activation on Swimming performance

You are invited to participate in a study entitled **The Effects of a Secondary Dryland Activation on Swimming performance** that is being conducted by Jeremy Bagshaw (MSc. Kinesiology Candidate). Jeremy is a graduate student in the department of Exercise Science, Physical and Health Education at the University of Victoria and you may contact him if you have further questions by phone: 250-418-1536, or email: jeremybagshaw@uvic.ca

As a graduate student, I am required to conduct research as part of the requirements for a degree in Master of Science in Kinesiology. It is being conducted under the supervision of Dr. Kathy Gaul. You may contact my supervisor at 250-721-8380 or kgaul@uvic.ca.

Background

Warm-up is necessary for exercise performance; it elevates heart rate, core temperature, decreases muscle stiffness and can provide neuromuscular activation, all of which can lead to improved exercise performance. Currently, at international competitions, there are long transition times between warm-up and performance, usually upwards of 30 minutes. These long transition times are due to a required 20 minute marshalling time before races. Research shows that gap times of longer than 20 minutes between traditional water-based warm up and swim performance can lead to decreases in athletic performance. Research has also suggested that by shortening the transition time between warm-up and performance we will see improved performance by enhancing the physiological state at which the athletes begin their race; transition times of 20 minutes or less have been suggested to be optimal for performance. This research will hopefully change the culture around warm-up protocols in swimming and help enhance swimming performance.

Purpose and Objectives

The purpose of this research project is to examine the effects of a dryland warm-up during the transition phase on 200 metre swimming performance. The objective is to provide supporting evidence that a secondary warm-up protocol

can enhance swimming performance which would lead to a change in the current culture around competition warm-up in swimming.

Importance of this Research

Research of this type is critical to improving swimming performance by addressing an issue that currently exists in the international competition format. Currently, there is plenty of research showing that by decreasing the time between warm-up and racing, performance can be improved. However, this research is not generalizable to an international competition setting as there are mandatory marshalling times that can extend the transition time up to 40 minutes. By contributing evidence that a secondary, dryland, warm-up during the transition phase could improve performance, it will encourage athletes and coaches to change the culture around competition warm up.

Participants Selection

You are being asked to participate in this study due to your current involvement in the High Performance Centre Victoria, are actively participating in regular center training, and have attained a senior national qualifying standard. As such, you are a good representative of the elite male and female swimming population across Canada.

What is involved?

This study involves the following procedures and protocols:

Testing sessions will take place during regular training at Saanich Commonwealth pool and will consist of four sessions spread out over four consecutive weeks.

Week 1

- Introduction to the dryland warm-up program; each athlete will be given an overview of the testing day and equipment being used on the Friday before the first testing session. A sample core temperature capsule will be shown during this session and the contraindications for taking the pill such as a narrow throat or difficulty in swallowing pills will be emphasized. This week will also have the first testing session on the Saturday.

Week 2, 3, 4: Testing day will follow the same timeline as the first session, without the introductory component the Friday.

Performance Test:

- 200-M Time Trial (conducted individually)
- Will be timed using a video camera set up on deck. From the video we will time from when the athletes feet leave the blocks to when they touch the wall.

Transition Phase Protocols:

- Passive Transition Phase
- Active Transition Phase
- Athletes will be randomly assigned to a transition phase during the first testing session
- The following testing sessions, athletes will alternate between the passive and active transition phases

Before arrival to the first testing day each participant will be assigned a participant number. This number will be used to record and track data. This participant number, rather than name, will be used throughout the study to ensure confidentiality of results.

Prior to each session participants will check in and any injuries sustained during the week which may prevent an individual from participation must be reported to the Principal Investigator (Jeremy Bagshaw). An overview of each session will be provided following check-in to prevent confusion throughout the session.

Detailed Overview

First day (week one):

Participants will check in at the beginning of each session; any injuries sustained preventing an individual from participation must be reported by the participant to the Principal Investigator (Jeremy Bagshaw) at this time. Your first session will consist of a detailed introduction to the warm-up program and testing format. You will be provided with a handout outlining the warm-up for you to take home. The morning of the testing session the participants will be given a temperature sensor capsule (Vital Sense, Phillips) to ingest. Core temperature will be monitored using a telemetry system (equivital, ad instruments, canada) and ingestible, biocompatible, telemetric capsules (mini mitter co., bend or). This system provides temperature values every 15 seconds to an accuracy of +/- 0.1 °c. The capsule will pass within 12-48 hours after ingestion. We will also measure ear temperature via a thermometer that is commonly found in medical clinics, hospitals and in private family homes (parents commonly use this device to measure fever in their children). It is a non-invasive way to measure inner ear temperature which is then used to reflect core temperature. The measures obtained will be used as a backup measurement to the core temperature capsules that the participants will have ingested. We will be measuring ear temperature at the completion of the in-pool warm-up and during the transition phase.

At the start of the testing session the athletes height and weight will be recorded for descriptive purposes, participants will then place the Polar OH1 heart rate monitor onto their upper arm. Swimmers will then complete their normal water-based warm-up protocol followed by either a thirty-minute passive transition

phase or thirty-minute active transition phase. The first ten minutes of both transition phases will allow for the athletes to put on their competition suit, and their standard Canadian National team tracksuit (jacket and pants), consistent with an international competition. Once changed, the passive transition phase participants will remain seated for twenty minutes in a simulated international competition 'ready room' environment. The active transition participants will sit for ten minutes then perform the 5-minute dryland activation protocol, followed by five minutes seated. Following the thirty minute transition phase each athlete will complete a 200 metre time trial in their primary stroke that will be timed using a Sony CX-45 video camera (Appendix 3B). Each participant will swim the same stroke for all four sessions.

Female Participants

At the beginning of each testing session a female researcher (Liz Johnson) will ask the female participants when they started their last menstrual period. This is due to the possible effect menstrual phase has on core temperature. This information will be collected in a private manner and kept confidential to the rest of the research team and will only be recorded on a separate data sheet using only the participant number codes.

Second/Third/Fourth day:

The protocols for the second, third and fourth three days of testing will be the same as the first testing session; the transition phase warm-up protocol for the day is the only component that will change between sessions. Participants will check in at the beginning of each session; any injuries sustained preventing an individual from participation must be reported by the participant to the Principal Investigator (Jeremy Bagshaw) at this time. By checking in you will consent to participation in the session that follows.

Risks

There are some potential risks to you by participating in this research. These include fatigue and a low risk of injury. No risk exists related to this study that is not present during your regular swimming training sessions.

To prevent or to manage these risks the following steps will be taken:

- a) All testing will be directed and conducted by the Principle Investigator (Jeremy Bagshaw)
- b) You will be familiarized with the equipment and protocols ahead of testing in order to minimize potential discomfort and any risk of injury. All methods will be explained and demonstrated in full prior to each session.
- c) The teams trainers and staff will be present at all data collection session, if any injury or discomfort is experienced by a participant the on-site staff is well trained and will take the necessary steps within the teams protocols in response to the situation. The staff present is the same staff present at all center training sessions and are well educated on how to handle situation.

In the case of a medical emergency the team trainers and staff will handle injuries and discomfort to assure team protocol is followed appropriately. All research staff has knowledge of human anatomy and will refer a participant to the team's trainers and staff if they feel a participant is showing signs of an injury or discomfort throughout the testing sessions.

Participation

You may be excluded from participation in the study if you have sustained an injury that may prevent safe and optimal performance of the warm up or the 200m performance swim. If you have been cleared to return to training and are no longer experiencing any repercussions from an injury, you can give consent to participate at your own discretion and parental support/consent (where appropriate). There are some contraindications associated with swallowing the telemetric capsule. Volunteers will be screened in regard to swallowing, through a series of questions prepared by a physician (appendix 3b). You will also be excluded if you are unable to swallow a large capsule. We have used the telemetric capsule on over 200 occasions in research at Uvic with absolutely no concerning issues.

Benefits

You will gain greater knowledge of the importance of appropriate warm up, the athletic performance tests will allow you to gain further knowledge of your own personal athletic capability, and you will have the opportunity to participate in a formal academic research project.

The study will also provide the swimming community further information on proper swimming warm-up timing protocol. This is an area that currently has little research and could greatly benefit athlete performance.

Voluntary Participation

The Head Coach of your program, Ryan Mallette, has approved this research project and is aware of your right to participate or not. The Head Coach is aware that not all athletes may want to take part in the research and have agreed to coordinate alternate training for those who chose not to participate in the research.

Your participation and involvement in this research must be completely voluntary and will in no way have any impact on your standing as an athlete within the High Performance Swimming Center Victoria. You have the right to decline the invitation to participate. Should you choose to participate, and later change your mind, you can withdraw at any time without judgment or personal repercussion and with no risk to your status in the Center. If you chose to withdraw, all data collected to date will be destroyed.

The head coach will not have access to individual testing results. He will only be given access to the final report that will not have any individual results.

Initial informed consent will be obtained through the collection of signed consent forms (this document) and when you check in at the beginning of each session, you are consenting to participating in the session to follow.

Anonymity

Given the nature of the research testing protocols, your Center teammates who also volunteer to participate in this study will be present during the time of testing, similar to your regular Center protocols. Therefore, your participation in the study cannot be fully anonymous.

Confidentiality

Athletes will be given participant ID numbers protecting their identity throughout the testing protocol. Athletes will not be referred to by name by the research staff. Testing protocols will include no verbal announcement of results and data collection sheets will be kept in the possession of the research team. Your confidentiality, and the confidentiality of your data, will be protected by the use of this participant code so that your results will not be identifiable to anyone other than the Principle Investigator and his supervisor. All paper data will be stored in a locked filing cabinet in McKinnon Building, room 171 in the School of Exercise Science, Physical and Health Education at UVIC and will have only participant codes identifying each participant.

Dissemination of Results

It is anticipated that the results of this study will be shared with others in the following ways: a written thesis, oral presentations, and published in a peer-reviewed academic journal. Upon completion, the written thesis will be made available publicly online via the university library. No individual results will be reported or published. Each participant will be given a copy of their individual testing results as well as a copy of the article submitted for publishing.

Disposal of Data

Data from this study will be disposed of within five years of study completion. Electronic data will be permanently erased and paper copies will be shredded. Video recordings of the races will be deleted once the performance time has been taken and within one week of the performance.

Contacts

Individuals that may be contacted regarding this study include:

- a) Jeremy Bagshaw, Principle Investigator
Phone: 250-418-1536
Email: jeremybagshaw@uvic.ca
- b) Dr. Kathy Gaul, Supervisor
Phone: 250-721-8380
Email: kgaul@uvic.ca.

In addition, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Human Research Ethics Office at the University of Victoria (250-472-4545 or ethics@uvic.ca).

The Human Research Ethics Board has approved this research project.

Your signature below indicates that you understand the above conditions of participation in this study, that you have had the opportunity to have your questions answered by the researchers, and that you consent to participate in this research project.

_____	_____	_____
<i>Name of Participant</i>	<i>Signature</i>	<i>Date</i>
_____	_____	_____
<i>PARENTS/ GUARDIANS</i>	<i>Signature</i>	<i>Date</i>

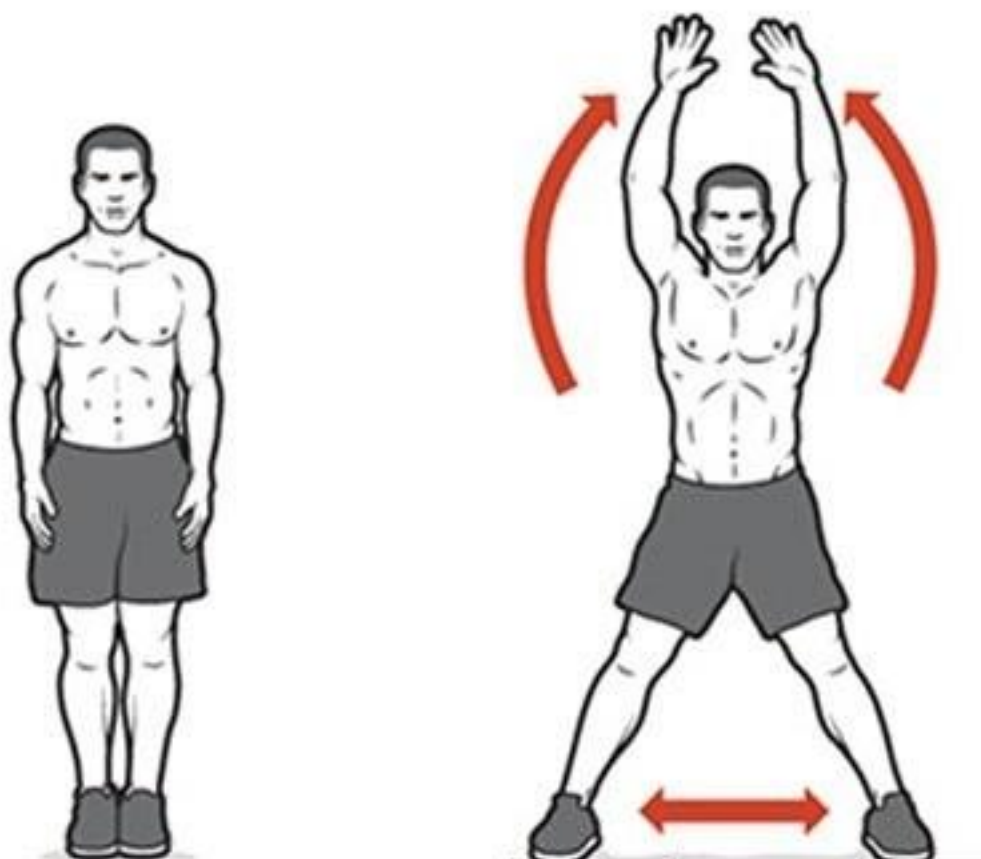
A copy of this consent will be left with you, and a copy will be taken by the researcher.

Appendix 3A Dryland Activation

Active Transition Phase Warm-up

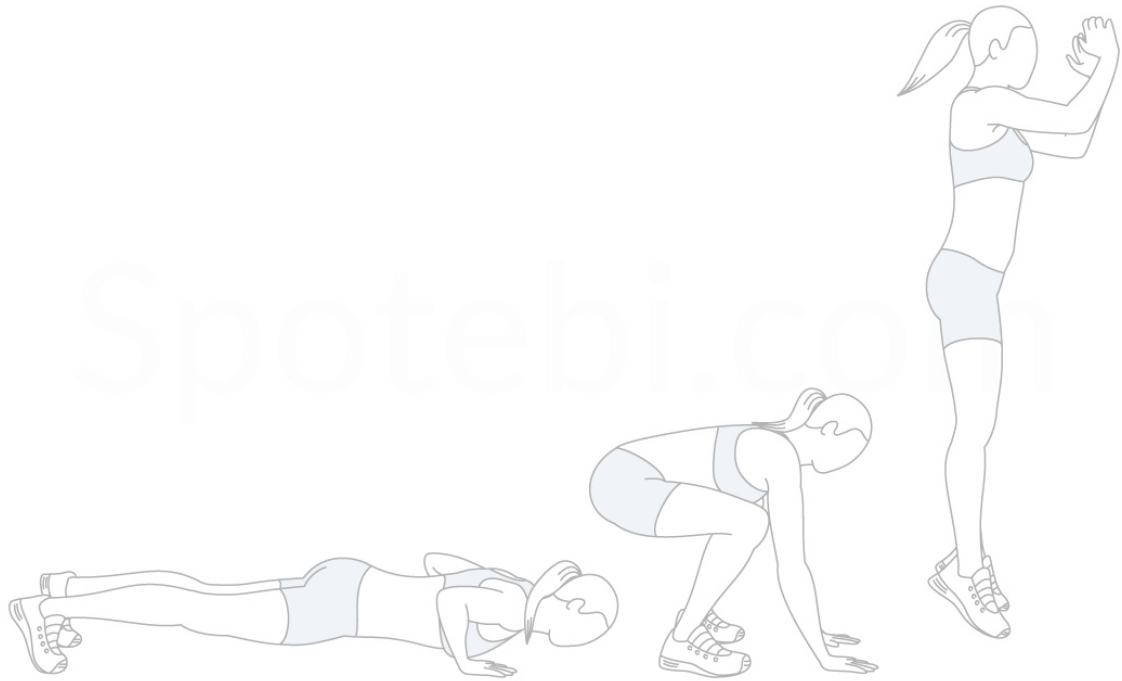
These are the exercises involved in the active transition phase. Each athlete will perform two sets of the following exercises; 40seconds of jumping jacks, 6 explosive burpees. This activation protocol was put together with consultation from the strength and conditioning coach of the Victoria High Performance Swim Center, Didie Hamell-Jollet.

Jumping Jacks:



This is an exercise that involves the athlete jumping on the spot while spreading their legs apart and raising their hands above their heads. This exercise will be performed for 30 seconds. It will increase the athlete's heart rate and core temperature. The athletes will perform 30 seconds of this exercise.

Burpee:



The athletes will start in a prone position with their chest on the ground, once in this position the athlete will do an explosive push-up, bring their legs into a squat position then perform an explosive squat jump. The athletes will perform this exercise for 6 repetitions.

Appendix 3B Standardized Instruments

Standardized Instruments

a. **Vital-sense Electronic Pill** (Vital Sense, Mini Mitter, Co. Inc., Bend Oregon) – to measure Core Temperature



b. **Polar OH1 Heart Rate Sensor** (Polar Electro Inc., Kempele, Finland) - to measure Heart Rate.



c. **Canon HF-R800** – to measure the time to complete 200m Time-Trial



e. Seiko S141 Stopwatch – to measure the time to complete 200m Time-Trial



Appendix 4 Bootstrap Data Analysis

The bootstrapped paired sample t-test indicated that HR increased significantly from Pre-pool warm-up ($M = 105 \pm 16$ bpm) to post pool warm-up ($M = 136 \pm 11$ bpm), this mean increase of 31 bpm was significant, ($t(17) = 5.76$, $p < .001$, BCa 95% CI [20.66, 40.00], $d = (1.83)$). Heart rate declined significantly over the first twenty minutes of both transition phase groups from a mean of 136 ± 11 bpm to 89 ± 13 bpm. This mean difference of 47 bpm was significant, ($t(17) = 14.15$, $p < .001$, BCa 95% CI [40.38, 53.39], $d = (4.02)$). The dryland activation resulted in an increase in heart rate ($M = 94 \pm 13$ bpm to 134 ± 22 bpm), this mean increase of 40 bpm was significant, $t(8) = 5.89$, $p < .003$, BCa 95% CI [27.56, 55.17], $d = (1.61)$. Mean heart rate was significantly higher at twenty-five minutes into the transition phase in the dryland group ($M = 134 \pm 22$ bpm) compared to the traditional group ($M = 84 \pm 13$ bpm), ($t(8) = 6.41$, $p = .006$, BCa 95% CI [35.00, 63.66] $d = (2.83)$). At all other time points during the transition phase there were no significant differences in HR between conditions.

The standard pool warm-up elevated mean core temperature from $37.63 \pm .31$ °C to $38.15 \pm .29$ °C in both groups. This mean increase of $.52$ °C was significant, ($t(17) = 8.25$, $p < .001$, BCa 95% CI [0.41, 0.64], $d = (1.80)$). Core temperature declined over both thirty-minute transition phases from $38.15 \pm .29$ °C to $37.43 \pm .60$ °C. This mean decline of $.72$ °C was significant, ($t(17) = 5.28$, $p < .001$, BCa 95% CI [0.49, 1.00], $d = (1.61)$). There was no significant difference in core temperature at any time between conditions.

The mean 200 metre time-trial performances were significantly faster in the dryland transition ($M = 130.61 \pm 10.46$ s) compared to the traditional transition ($131.71 \pm$

11.07s), ($t(8) = -3.35$, $p < .022$, BCa 95% CI [0.52, 1.73], $d = (.11)$). There was a significant difference in mean third 50 metre split between the dryland transition phase ($M = 34.83 \pm 4.28$ s) and the traditional transition phase (35.47 ± 4.47 s), ($t(8) = -2.97$, $p < .039$, BCa 95% CI [0.24, 1.01], $d = (.15)$). There were no other significant differences in splits between the two transition phase conditions.

The differences in HR and T_{core} represented large effect sizes, while the differences in performance time represented small effect sizes.