AN INVESTIGATION OF THE EFFECTS OF DIFFERENT WARM UP TECHNIQUES ON RACING GREYHOUNDS BEFORE EXERCISE

BRÍD O'SULLIVAN (98383622)

Submitted as part requirement for the Postgraduate Degree of MSC Veterinary Physiotherapy, Angila Ruskin University, Writtle School of Agriculture, Animal and Environmental Sciences, July 1st, 2024

Abstract

Greyhound racing can often be demanding for canine athletes. As publicity of greyhound racing expands and participation escalates, there becomes a greater requirement for an understanding of the various warmup techniques available surrounding effects on canine performance. Continual use of kinematic analysis of canine stride length (SL) and range of motion (ROM) has determined a need for warmup to be implemented as part of data for analysis of studies to be accomplished. The objective of this experiment was to measure the effects of various warmup techniques on the kinematics of racing greyhounds prior to exercise, at three different stations of gallop, start station (station 1), middle station (station 2) and finish station (station 3). The investigation imposed a crossover arrangement in which six racing greyhounds were randomly prescribed protocols of heat (heat packs), massage (effleurage and tapotement), aerobic warmup (trot), and no warmup, which acted as a control. Six joints were chosen: glenohumeral joint, elbow joint, carpus joint, coxofemoral joint, stifle joint and tarsus joint.

Kinematic analysis, utilising Quintic biomechanics software (v29, Quintic Consultancy Ltd, Birmingham, UK), measured SL, ROM, and time performance after the warmup techniques were implemented, which determined and measured limb angulation, acceleration/deceleration, and velocity of chosen anatomical makers (Bockstahler *et al.,* 2007; Silva *et al.,* 2014; Carr & Dycus, 2016). Determined on data normality, a one-way repeated measures ANOVA or a Friedman test was carried out using SPSS Statistics software (version 29, IBM Corporation, Armonk, New York, USA). Heat, massage and trot did not significantly increase stride SL, ROM, or time at any of the stations or as a whole over the course of the gallop. Statistical analysis highlighted that there were no statistically significant effects of any of the warmup protocols on SL, ROM, or time of racing greyhounds.

This experiment portrayed that although heat, massage and trot have a probable future to prevent injury in high demanding sports creating muscle resilience, through protocols that could be comfortably linked in practise. The effects of an increase in SL, enhancement in ROM, and improvement in time, in the context of warmup, on the risk performance enhancement and risk of musculoskeletal injury is indeterminate.

However, these findings may possibly accommodate veterinary physiotherapists with support for essential research on the impact warmup protocols have on racing greyhounds prior to exercise, to reduce the prospect of musculoskeletal injury, which is a considerable matter for retirement.

Table of Contents

Abstract……i

List of abbreviations……x

Acknowledgements……xi

1. Introduction……1

2. Literature review……2

2.1 The importance of warmup before exercise……2

2.2 Greyhound racing……3

2.3 The racing greyhound……4

2.4 Heat……5

2.5 Massage……7

2.6 Trot……9

2.7 Rationale……11

2.1.1 Aim……13

2.1.2 Objectives……13

2.1.3 Hypothesis……13

2.1.4 Null hypothesis……13

3. Methodology……14

3.1 Ethical considerations……14

3.2 Subjects……15

3.3 Experimental design……17
3.4 Warmup techniques……18
3.5 Data collection……20
3.6 Data analysis……25
3.7 Statistical analysis……26
4. Results……27
4.1 SL station 1……27
4.1.1 SL station 2……28
4.1.2 SL station 3……29
4.1.3 Summary of SL……30
4.2 Glenohumeral ROM station 1……30
4.2.1 Glenohumeral ROM station 2……31
4.2.2 Glenohumeral ROM station 3……32
4.3 Elbow ROM station 1……33
4.3.1 Elbow ROM station 2……34
4.3.2 Elbow ROM station 3……35
4.4 Carpal ROM station 1……36
4.4.1 Carpal ROM station 2……37
4.4.2 Carpal ROM station 3……38

4.5. Coxofemoral ROM station 1……39

4.5.1 Coxofemoral ROM station 2……40

4.5.2 Coxofemoral ROM station 3……41

4.6 Stifle ROM station 1……42

4.6.1 Stifle ROM station 2……43

4.6.2 Stifle ROM station 3……45

4.7 Tarsal ROM station 1……46

4.7.1 Tarsal ROM station 2……47

4.7.2 Tarsal ROM station 3……48

4.7.3 Summary of ROM……49

5.1 Time……50

5.1.1 Summary of time……50

6. Discussion……51

6.1 SL……51

6.1.1 Heat……51

6.1.2 Massage……53

6.1.3 Trot……54

6.1.4 Summary of SL……54

6.2 ROM……55

6.2.1 Heat………………………………………………………………………………..……………..………56

6.2.2 Massage………………………………………………………….…………………………….….….….56

6.2.3 Trot…………………………………………………………..……………………………..……….…..57

6.2.4 Summary of ROM………..…………………………………………………..…………….….……58

6.3. Time…………………………………………………………………………….……………….…….…58

7. Conclusion…………………………………………………………………………………………..…59

8. Reference List……………………………………………………………………..……….………60

9. Appendices……………………………………………………………………………..…….…..…84

Appendix 1: *Table 1: Commonly massage techniques used on canines – edited from* Corti, (2014)………………...84

Appendix 2: Recommendations and practical application for further study……………………………………86

Appendix 3: Limitations of the systematic review process……………………………………………………87

Appendix 4: Limitations of the study…………………………………………………………….…………89

List of Tables……………………………………………………………………………..………………………

Table 1: *Commonly massage techniques used on canines – edited from* Corti, (2014)……………………….……84

Table 2: *Details of the individual subjects, including age, sex, and body condition score………………………………………………………………………………………….……….16*

Table 3: *Subject and treatment order during data collection………………..………………………...……….18*

List of Figures………………………………………………………………………………………………………

Figure 1: *Fortnight alterations in active ROM (in degrees) amid groups. Group 1 was the control group and did not include the stretching protocol, group 2 accomplished the stretching protocol only, group 3 achieved active heel raises to warmup the muscle before stretching, group 4 acquired superficial, moist heat from hot packs for 15 minutes prior to doing the stretching protocol, and group 5 received 7 minutes of continuous ultrasound prior to achieving the stretching protocol (*Nakano *et al.*, 2012)………………………………………………………..………..6

Figure 2: *Mean changes (±95% CI) between the first and second sprints after warmup stimulating stride frequency (WUF) and warm-up stimulating SL (WUL) in humans (Gil et al., 2021)…………………….………………………..10*

Figure 3: *The effect of heat, massage, trot, and no warmup on mean SL station 1 (meters). Error bars serve as standard deviation (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test…………………………………………………………………………………………..……………….28*

Figure 4: *The effect of heat, massage, trot, and no warmup on mean SL station 2 (meters). Error bars serve as standard deviation (n=4). No statistical significance (NS) is recorded (p<0.05) by Friedman's test………………………………………………………………………………………..……..……….28*

Figure 5: *The effect of heat, massage, trot, and no warmup on mean SL station 3 (meters). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test………………………………………………..……………………………………………………29*

Figure 6: *The effect of heat, massage, trot, and no warmup on mean shoulder ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test……………………………………………………………………………………………..31*

Figure 7: *The effect of heat, massage, trot, and no warmup on mean shoulder ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p<0.05) by Friedman's test……………………………………………………………………………………………….………………32*

Figure 8: *The effect of heat, massage, trot, and no warmup on mean shoulder ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test……..……………………………………..…………………………………...………………33*

Figure 9: *The effect of heat, massage, trot, and no warmup on mean elbow ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test……………………………………………………………………………………..………..34*

Figure 10: *The effect of heat, massage, trot, and no warmup on mean shoulder ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p<0.05) by Friedman's test……..……………………………………………………………………………………..………………..….35*

Figure 11: *The effect of heat, massage, trot, and no warmup on mean elbow ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test………………………………………………………………………………………..……..36*

Figure 12: *The effect of heat, massage, trot, and no warmup on mean carpal ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test………………..……………………………………………………………………..……37*

Figure 13: *The effect of heat, massage, trot, and no warmup on mean carpal ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test………………..………………………………..…………………………………...……..38*

Figure 14: *The effect of heat, massage, trot, and no warmup on mean carpal ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test…………………..…………………………………………..……………………..………..39*

Figure 15: *The effect of heat, massage, trot, and no warmup on mean* coxofemoral *ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test…………………………………………………………………………..………………………40*

Figure 16*: The effect of heat, massage, trot, and no warmup on mean* coxofemoral *ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test……………………………………………………………………………………………………...41*

Figure 17: *The effect of heat, massage, trot, and no warmup on mean* coxofemoral *ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test………………………………………………………………………………………..42*

Figure 18: *The effect of heat, massage, trot, and no warmup on mean stifle ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test………………………………………………………………………………………43*

Figure 19*: The effect of heat, massage, trot, and no warmup on mean stifle ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test…………………………………………………………………………………………..44*

Figure 20*: The effect of heat, massage, trot, and no warmup on mean stifle ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test……………………………………………………………………………………………..45*

Figure 21: *The effect of heat, massage, trot, and no warmup on mean tarsal ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test………………………………………………………………………………………….47*

Figure 22: *The effect of heat, massage, trot, and no warmup on mean tarsal ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test……………………………………………………………………………………………48*

Figure 23: *The effect of heat, massage, trot, and no warmup on mean tarsal ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p<0.05) by Friedman's test……..49*

Figure 24: *The effect of heat, massage, trot, and no warmup on mean time (seconds). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p<0.05) by Friedman's test……………………………………………………………………………….……….……….……………..50*

Figure 25: *An example of a PRISMA flow diagram by Robertson-Dixon et al., 2023, similar to what was followed in the current study…………………………………………………………………………………………..89*

Figure 26: *Alteration of time trial performances (in seconds) in comparison to 5 (temperature). Solid line portrays mean value with 95% confidence interval bars. Gray area highlights estimated CV (±3.0%, which relates to 15 seconds) of rowing and running trials. Change values are calculated to ensure slower times occur as positive number (Spitz et al., 2014)…………………………………………………………………….……..……..…..91*

List of Plates……………………………………………………………………………………………….……….

Plate 1*: All subjects lined up for static and dynamic assessment with supervisor – (authors own 2024)…………......15*

Plate 2: *Subject 3 returned back to kennel after data collection – (authors own, 2024)………………………………………………………………………………………………………......17*

Plate 3: *Subject's receiving different warmup techniques prior to being exercised on the gallop. (1. Heat, 2. Massage, 3. Trot, 4. No warmup) – (authors own, 2024)…………………………………………….……..…….20*

Plate 4: *Reflective markers placed on the subject seconds before being exercised on the gallop. Metacarpal and metatarsal V not marked due to visibility issue with tracking -(authors own, 2024)……….…………………………...22*

Plate 5: *The tripod station set up to record the subjects from a lateral aspect, right side station 1 (start), station 2 (middle) and station 3 (finish) – (authors own, 2024)…………….……………………………………………………..23*

Plate 6: *Built in timing system with beams placed on the gallop, one set at take-off (start) and one set when slowing down (finish) to accurately start the time of each subject's performance – (authors own 2024)………………………24*

Plate 7: *(1) Handheld timing device which automatically prints off times of each subject once passed the second set of beams and (2) Lure used throughout data collection – (authors own, 2024)………….…………….…………...25*

List of abbreviations

ROM	Range of motion
SL	Stride length

Acknowledgements

Firstly, I would like to thank Jade Terry for always guiding me in the right direction and answering all my queries. Secondly, I would like to thank each individual family member for taking part and helping me to accomplish this research project. It goes without saying that I would not have gotten through this degree without the continous support of my loving parents Úna and John. Having lost my dear Mum over the last year, her support has always driven me forwards and her presence was throroughly felt throughout the completion of this project.

Word count: 14,983

1. Introduction

Warmup is of immense importance for all species prior to exercise, not only to compete but to thrive in locomotion in competition. Moreover, the canine encounters plenty of assorted styles of warmup due to the sports they partake in. Society today, has not limited variation in sports, including agility, racing, herding, and hunting. Over the years, history has provided dogs to be selectively bred with required traits in order to continue these roles and sports (Kim *et al.,* 2018).

Due to our advancement in veterinary knowledge, and the value of warmup within society, the attention to comprehend and advocate the correct warmup techniques needs to be recognised. Canine warmup techniques have subsequently been of interest and investigated over the past 20 years (Okazaki *et al.,* 1993; Sicard *et al.,* 1999; Bishop, 2003; Drum *et al.,* 2015; McCauley & Van Dyke, 2018; Farr *et al.,* 2020; Fuglsang-Damgaard *et al.,* 2021).

In addition, despite the influence of physiotherapy being continuously proven in animals, knowledge of physiotherapeutic warmup methods prior to exercise is necessary to continue enhancement of knowledge (Dybczyńska *et al.,* 2022). Also, with the raised number of sports in which canines are exposed to (Betram *et al.,* 2000), because of the roles humans have accustomed them to over the years, it is essential that endless enhancement of expertise is supported for both canine wellbeing and welfare with adjoining partnership among the veterinary physiotherapist and the veterinarian (Colborne *et al.,* 2005; Carr *et al.,* 2015; Gustås *et al.,* 2016).

Moreover, the concept that racing greyhounds are less likely to suffer an injury due to their conditioned state is arguably flawed. Thus, while less likely to fatigue quickly it is also possible to exceed the tissues' ability if not warmed up correctly. Furthermore, racing greyhounds are also on the edge of over exceeding ability of muscle fibres and elasticity due to continuous strain and lack of competition preparation (Nelson *et al.,* 2001). To continue, approaches surrounding canine warmup techniques within greyhound racing, must be a utilised skill before exercise to ensure maximum performance is reached and to reduce injury rate. Additionally, a deeper insight into the effects of different warmup protocols in the racing greyhound would help guide veterinary physiotherapists when assigning unique tailored rehabilitation plans which clinically justify each individual's needs.

2. Literature review

2.1 The importance of warm up before exercise

It is vastly acknowledged that warming up before exercise is crucial for the fulfilment of flawless performance. Both active/passive warmup can provoke neural, psychology-related effects, also, escalation in exalted oxygen uptake kinetics, anaerobic metabolism, and post-activation potentiation (McGowan *et al.,* 2015). The concept of using passive warming protocols is to retain exalted core and muscle temperature during the transition phase which is the stage amid accomplishment of warmup and the beginning of the competition (McGowan *et al.,* 2015). Additionally, the use of warmup prepares the canine physically and psychologically allowing them to perform most effectively (Alanazi, 2016; Loya, 2020; Au, 2022). Furthermore, the aim of warmup is to enhance performance and diminish the prospect of muscle damage from occurring (Loya, 2020; Au, 2022; Tomlinson & Nelson, 2022). Thus, warmup is used within veterinary physiotherapy to help raise muscle temperature and metabolism along with muscle fibre function resulting in an increase of soft tissue flexibility (Fradkin *et al.,* 2010; Page, 2012; Parr *et al.,* 2017; Loya, 2020; Au, 2022). In addition, fatigue has a detrimental effect on canine movement/performance, increasing injury risk, therefore, metabolism must be enhanced using warmup to help remove waste products such as lactic acid from the body (Tomlinson & Nelson, 2022). Therefore, it is critical that owners/trainers understand the importance of warmup protocols which may help stimulate different muscle groups. Warmup involves practicing movement, resolving soft tissue restrictions and adhesions within the kinetic chain using a certain technique (Parisi, 2022). A warmup should consist of a ritual that one should look forward too independently before exercise of any description (Harker, 2022).

Agility dogs that train for less than one hour a week use more muscle fibres within the *m. triceps* to complete a simple direct trotting task after warmup compared to a fit racing greyhound trained regularly (Tomlinson & Nelson, 2022). Kulund *et al.,* (1983) states that an active warmup e.g., trot is more effective than passive warmup e.g., massage/heat. Specific movements must be utilised for specific sports targeting main muscles required for racing (Kulund *et al.,* 1983). To continue, warmup is more commonly used for agility dogs, rather than infrequent warmup which is common within the greyhound industry (Inkilä *et al.,* 2022). Furthermore, the usual length of warmup for agility dogs varied from five minutes to more than half an hour (Birch & Leśniak, 2013; Inkilä *et al.,* 2022). In contrast many studies have found warmup to be inconclusive regarding injury rates (Steele *et al.,* 1999; Fradkin *et al.,* 2006; Cullen *et al.,* 2013). Additionally, in human investigations stretching as a warmup protocol proposed most popular amongst various sports and injury rates, specifically running (Gleim & McHugh, 1997; Thacker *et al.,* 2004; Grooms *et al.,* 2013; Behm *et al.,* 2016).

2.2 Greyhound racing

Greyhound racing is an organised, sport which requires greyhounds running around an oval track anticlockwise (Granatosky, 2022). Moreover, it involves utilizing an artificial lure that is controlled by the hare driver travelling on a rail in front of the dogs until the greyhounds cross the finish line (Granatosky, 2022). Thus, the lure is then covered, and the greyhounds cannot see it at the pickup area once the race is finished. Greyhound racing peaked throughout the first half of the twentieth century especially favoured among working-class communities, for whom evening racing and tracks in urban areas were available (Poulter, 1991; Baker, 1996; Ray, 2001; Thompson, 2003). The first ever greyhound race meeting was held at Belle Vue in Manchester in 1926 and by 1927 the White city in London was estimating 100,000 people per meeting as the sport soared with enthusiasm (Morris, 2014). Today, the absence of science-based research regarding the public awareness of greyhound racing in New Zealand have donated to governing bodies' absence of perception of danger to the industry's social license which has ultimately created a negative stigma around the sport and the benefits of the industry (Liam Delaney, 2006; Palmer *et al.,* 2020; Cameron *et al.,* 2024).

The aim of implementing warmup as part of veterinary physiotherapy is to create a holistic avenue to progress musculoskeletal health within all sporting disciplines and to improve the perception of greyhound racing globally.

2.3 The racing greyhound

Compared to man, the greyhound has a very high oxygen uptake during sprinting. Sprinting aids respiration in the greyhound (Staaden, 1984). Furthermore, trainers implement training rituals that aim to equip greyhounds for race-day by acquainting a high-intensity speed workout throughout the week which is organised and measured to condition the greyhounds for the metabolic and physiological demands of sprint racing (Palmer *et al.,* 2020). Moreover, training/racing regimes have been highlighted as crucial aspects linked with racing greyhound success and welfare (Palmer *et al.,* 2020). Certain muscles such as the *m. iliocostalis lumborum* and *m. longissimus dorsi* enhance power production of the greyhound when in motion facilitating spinal extension during gallop augmenting hindlimb muscle power (Webster *et al.,* 2014). The greyhound is one of the fastest land mammals ever to grace our planet competing in racing in numerous countries (Morris, 2014; Carr, 2015; Starling *et al.,* 2020). Thus, the greyhound is the only dog to be mentioned in the catholic bible dating back to centuries highlighting the importance of their existence over the centuries (Morris, 2014).

Sporting dogs have a high injury rate of 25% approximately (Brunke *et al.,* 2023). The mammalian skeleton has a particular ability to react to adaptations in mechanical loading in the short term, therefore, optimise for energetic efficiency in relation to sudden adaptations in mechanical demands (Goodship & Smith, 2008). Regarding the greyhound, frequency of incidence is high due to reoccurring asymmetrical mechanical loading leading to fractures of the tarsus being the most common injury (OST *et al.,* 1987; Guilliard, 2000; Johnson *et al.,* 2010).

Racing greyhounds have accustomed numerous flexible physiological traits that categorise them from various breeds, regarding musculoskeletal conformation and developed myocardial muscle, both of which enhance exercise capabilities (Tharwat *et al.,* 2014). Additionally, they are subject to an array of biochemical/physical alterations due to racing.

Correspondingly, specific high intensity training is involved, and different warmup techniques before training help target different anatomical areas. The correspondence amid micro damage, bone fatigue, and healing through adaptive remodelling is influenced by the repetition of racing, along with the extent of constant cyclic loading continuous throughout racing and training (Palmer *et al.,* 2020), highlighting the relevance of warmup to prevent injury. Additionally, injury rates have been seen to be higher in higher grades of racing correlating speed with injury with lack of warmup and reduced body temperature (Sicard *et al.,* 1999). Today, there are more participants than ever in canine sports competitions highlighting how warmup must be included in a balanced fitness program guided and provoked by veterinarians and veterinary physiotherapists (Hagler, 2017). The ability to twist and change to another plane mid-flight requires a high degree of core strength and balance as explosive forces cause a recoil on the digits/phalanges of the pelvic limb as the lumbar region drives power to complete maximum flexion/extension of joints (Robertson & Mead, 2013). Overall, skeletal muscles are the main driving force for moving the greyhound over the racetrack and the care of the juvenile racing greyhound will set the basis for future racing success or failure (Blythe *et al.,* 2007).

2.4 Heat

It has been illustrated by Kim *et al.,* (2019) that heat therapy applied over the thighs in humans has extensive fatigue defiance. Therefore, this highlights that heat therapy advances the restoration of fatigue defiance after eccentric exercise and enhances the expression of angiogenic influences in human skeletal muscle Kim *et al.,* (2019). Moreover, further investigations in animal studies have shown that acknowledgement of heat therapy notably improves skeletal muscle regeneration (Kim *et al.,* 2019). Similarly, heat may abolish the strain caused by uninformed lengthening contractions in humans and enhance quick practical recovery, (highlighted in Figure 1). Thus, promote the expression of genes that are crucial for skeletal muscle angiogenesis, which is the general remodelling counter to eccentric exercise (Kim *et al.,* 2019). Qadeer *et al.,* (2020) highlighted that applying heat therapy before exercises helps reduce discomfort in females with chronic musculoskeletal pain rather than enhance performance. Although, a limitation of this study consists of only one sex.

In contrary, the lack of or very thin hair over the hindlimbs in greyhounds commit to the loss of heat, as it is known that the thickness of the hair coat influences the insulation capacity of the animal (Vainionpää *et al.,* 2012). Superficial heating agents like heat packs have the most influence on cutaneous blood vessels, due to the exquisite temperature alteration within the first 1 cm of tissue depth (Heinrichs, 2004). In contrast, Steiss, & Levine, (2005) says that superficial heating penetrates to tissue depths up to approximately 2cm. Correspondingly, the release of chemical mediators like prostaglandins/histamines causes vasodilation to occur (McCutcheon *et al.,* 1999; Heinrichs, 2004). Thus, bradykinin is released which aids in relaxation of smooth muscle walls (Heinrichs, 2004).

Furthermore, muscle relaxation causes a reduced firing rate of gamma afferents and type II muscle spindle afferents, along with as elevated firing rate of type II fibres of the Golgi tendon organs (Heinrichs, 2004).

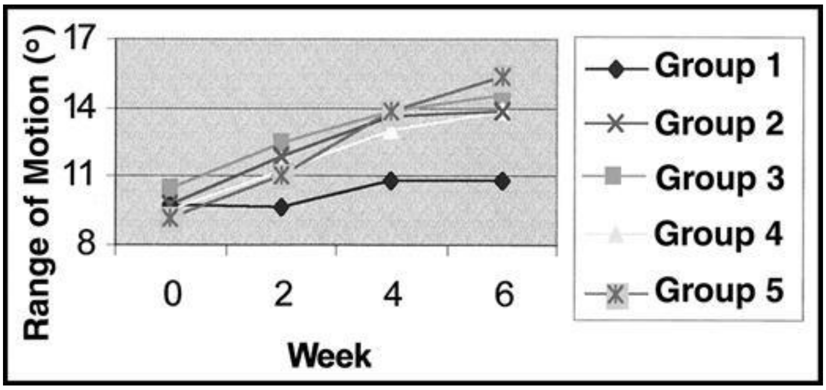


Figure 1*: Fortnight alterations in active ROM (in degrees) amid groups. Group 1 was the control group and did not include the stretching protocol, group 2 accomplished the stretching protocol only, group 3 achieved active heel raises to warmup the muscle before stretching, group 4 acquired superficial, moist heat from hot packs for 15 minutes prior to doing the stretching protocol, and group 5 received 7 minutes of continuous ultrasound prior to achieving the stretching protocol (*Nakano *et al.,* 2012).

The use of heat allows for analysis of performance changes and is largely attributed to temperature related mechanisms, although usually combined with stretching/aerobic exercise (Knight *et al.,* 2001; Bishop, 2003). Tissue is usually heated to 40 to 45C for 15 to 20 minutes prior to exercise (Millis, 2006). The pelvic limb anatomy of cursorial quadrupeds seems to be specially designed for achieving a high-power output (Williams *et al.,* 2008). Unsurprisingly, the *m. biceps femoris* has been noted as the powerhouse, extending the hip, stifle and tarsus, reliant on torque generation at the hip, retracting the pelvic limb in order to drive the centre of mass forward when racing, accelerating the body, whilst the caudal part of the muscle flexes the stifle (Usherwood & Wilson, 2005; Williams *et al.,* 2008; Roberston & Mead, 2013). Overall, warming up muscle groups is critical to prevent fatigue or injury when racing, (Ishac & Eager, 2021), although heat used as a successful protocol alone has yet to be deciphered.

2.5 Massage

The word massage originates from the verb *masser* borrowed from the French, which refers to soft tissue manipulation (Weerapong *et al.,* 2005; Robinson *et al.,* 2015). Effleurage assembles endogenous basal mesenchymal stem cells into circulation, which are linked with anti-inflammatory responses (Zaworski *et al.,* 2014; Riley *et al.,* 2021). Massage can be successful for post-race preparation and accelerated rehabilitation amid continuing competitions, with up to 60% of sled dogs having areas of muscle damage (Huneycutt & Davis, 2015). As far as the author is aware, no research to date has focused on massage alone as a pre-event protocol in canine studies. Moreover, there are certain techniques widely known to practitioners and used in society today (see Appendix 1: Table 1). This current investigation will apply a stimulatory mechanism to ensure maximum muscle preparation activity, therefore, effleurage and tapotement will be implemented.

The idea of starting with effleurage acquaints the subject to manipulation accustoming them to following techniques (Callaghan, 1993; Cartlidge, 2014). Effleurage enhances circulation, blood/lymph flow and increases temperature of the targeted area (Drum *et al.,* 2015; Best & Crawford, 2017; Baish *et al.,* 2022). Thus, this helps the evacuation of waste products such as chemical irritants/lactate acid, aiding fatigue post event (Tiidus, 1997; Mori *et al.,* 2004; Munk *et al.,* 2012). Furthermore, a raise in oxy- and deoxyhaemoglobin and blood flow concentrations in deeper muscle tissue after 5 minutes of effleurage and petrissage increases oxyhaemoglobin concentrations and maintains a resemblance of muscle oxygen metabolism post-massage, which succeeding orderly encourages clearance of lactate (Munk *et al.,* 2012). On the contrary, Mori *et al.,* (2004), highlighted a decrease in muscle fatigue by utilising an analogue scale, although it is difficult to decipher what exact techniques were used, lacking reliability.

Bergh *et al.,* (2022) found that effleurage has some degree of positive influence on heart rate and portraying a general relaxation influence rather than on performance. Similarly, reduction in anxiety and stress have been achieved by effleurage (Mille *et al.,* 2022), however no increase in deep muscle temperature has been identified on the *m. vastus lateralis* after 5,10, or 20-minutes states Drust *et al.* (2003), suggesting that effleurage may not be a relevant warmup technique prior to exercise. That said, similar limitations to Qadeer *et al.,* (2020) as this study consisted of males only.

Tapotement is often applied to athletes as a form of massage involving brisk, rhythmic percussion administered by fingers used as a stimulatory pump to encourage muscle fibre excitement (Formenton *et al.,* 2017; Coates, 2018). Moreover, cupping/slapping/hacking are three variations of tapotement provoking muscle readiness (Weerapong *et al.,* 2005; Robinson *et al.,* 2015).

That said, it is recognised that the cutaneous reflexes provoked from tapotement evoke miniscule muscle contractions (Dimitrijevic *et al.,* 1980; Martin *et al.,* 1988), although to the author's awareness, to date there is no clinical confirmation to determine this concept. Additionally, effleurage/tapotement combined could be a beneficial mechanism to implement before exercise in order to encourage motor performance and as a result, improve ROM stability, which would potentially reduce the likelihood of injury and provoke maximum performance (Wilson, 2002; Robertson & Mead, 2013).

A New Zealand investigation portrays that 26% of dressage riders utilise various forms of massage for their equines and the prime explanation for requiring veterinary physiotherapists to treat horses was due to back discomfort (Bergh *et al.,* 2022). Similarly, a Swedish investigation, highlighted that massage is especially used for back issues in equines (Bergh *et al.,* 2022). According to Herman *et al.,* (2012), applying practical neuromuscular warmup techniques can decrease acute injury incidence in young athletes. Furthermore, an international investigation, regarding equine veterinarians regarding rehabilitation modalities they mainly used, declared 69% used massage (Bergh *et al.,* 2022). In comparison, Riley *et al.,* (2021) portrayed that massage in canines may dramatically diminish myofascial and musculoskeletal discomfort severity noted by veterinary physiotherapists and owners linked to posture, gait, behavioural and performance problems, and reduction in day-to-day activities. Hill & Crook, (2010) highlighted that caudal musculature massage in horses significantly improved active hindlimb protraction in eight horses as well as enhancing hip ROM.

2.6 Trot

A brisk jog before exercise is a common form of low intensity aerobic activity in human studies (Faigenbaum & McFarland Jr, 2007). It is particularly used to equip the musculoskeletal and cardiovascular system for advanced vigorous physical activity as it increases blood flow, which activates muscle especially fast twitch muscle fibres, increases aerobic capacity, enhancing power production, ROM, and reducing chances of reoccurring injuries (Steiss, 2002; Faigenbaum & McFarland Jr, 2007; Avedesian *et al.,* 2018; Blazevich & Babault, 2019).

A systematic review noted that 79% of the investigations included portrayed enhanced performance after using a variety of warmup techniques (Jeffreys, 2021). According to Bishop, (2003) & McGonagle *et al.,* (2013) active warmup such as a trot results in marginally higher improvements in SL in short bursts of exercise than those achieved by passive heating. Gil *et al.,* (2021) noted that athletes finished faster with trot combined with other warmup regimes (Figure 2). In addition, Tiidus, (1997), found that light exercise in human studies is possibly more useful than massage in enhancing muscle blood flow and perhaps encouraging healing, and temporarily decreasing delayed onset of muscle soreness after exercise.

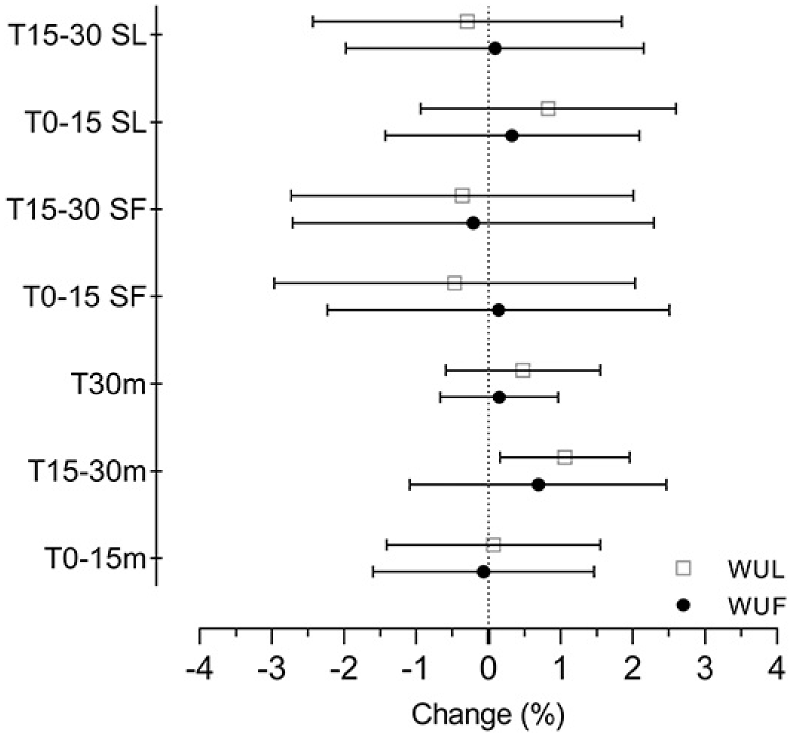


Figure 2: *Mean changes (±95% CI) between the first and second sprints after warmup stimulating stride frequency (WUF) and warmup stimulating SL (WUL) in humans (Gil et al., 2021).*

It has been noted that the *m. gastrocnemius* muscle in greyhounds has a statistically significant raise in superficial temperature with the use of trot as warmup (Repac *et al.,* 2020). In comparison, another investigation with the use of a 12-minute trot in military dogs found that *m. biceps femoris* had a significant raise in temperature (Repac *et al.,* 2020). Thus, increasing muscle activity levels incorporates the warming of deeper areas and stabilising muscles (Robertson & Mead, 2013). An effective warmup should only take around 2 to 3 minutes including a trot and active stretching to enhance ROM, never exceeding what is expected or required throughout racing (Hagler, 2017). In contrast, Foster (2013) states that fifteen minutes of trot should be completed before exercise. Similarly, Tyler *et al.,* (1996) & McGonagle *et al.,* (2013) portrayed that more than 70% of energy supply is from aerobic energy sources and that this input is higher when equines/canines have acquired a 5-minute trot warmup prior to high intensity exercise. This investigation was analysed on fifteen fit thoroughbreds which are frequently exercised, like the subjects in this investigation.

In comparison, a study conducted by Lund *et al.,* (1996) & Gray & Nimmo, (2001) highlighted a significant increase in oxygen levels in fit thoroughbreds and muscle temperature after active warm up in eight male cyclists. Although, the bulk of investigations revolve around human and equine studies it may potentially be limiting the generalisability of these results to the wider population as stretching is a predominant regime rather than trot (Stewart & Sleivert, 1998; Chatel *et al.,* 2021; Paris, *et al.,* 2021). Subsequently, it is challenging to appraise the effect trot has in these investigations.

In regard to SL, to the authors knowledge only two studies investigating trot as a warmup are available, both of which revolve around human studies, competitive swimming and running, with no statistically significant analysis reported on SL, although time of completion improved 0.5% (Neiva *et al.,* 2014; Morouco *et al.*, 2017).

Although, the ideal warmup period for canines has yet to be fully proposed, some propositions prevail for racing greyhounds that 5-10 minutes of trotting post-race is noted as satisfactory (Blythe *et al.,* 2007). The profitable influences of 5-15 minutes of active warmup were further promoted by improved SL and ROM in racing greyhounds (Fuglsang-Damgaard *et al.,* 2021). Regarding the suggestions of Blythe *et al.,* (2007) and Steiss *et al.,* (2002), 10 minutes of trot will be completed in this study.

Thus, this will be investigated using 2D motion capture providing a non-invasive and accurate insight into the influence of warmup while permitting an objective examination of biomechanics (DeCamp 1997; Carr *et al.,* 2013). Furthermore, Quintic biomechanics software will be required for this investigation in order to track reflective markers placed on anatomical locations necessary for kinematic evaluation and biomechanical analysis (Hurrion, 2009; Hall *et al.,* 2016; Singh, 2018).

2.7 Rationale

Different warmup techniques have different effects on joints but overall have an affirmative performance impact (Silva *et al.,* 2018). Correct weight bearing, and limb use are some of the extensive benefits warmups provide (Drum *et al.,* 2015). A warmup regime enhances physiological/metabolic rates, enhances blood pressure and oxygen availability to muscles, encouraging glide of the muscle fibres which as a result decreases chance of strains, permitting nerve impulses to travel more efficiently providing the chance of better performance (Davies, 2013; Zink, 2014).

Also, warmup must include techniques that recapitulate the amount of flexion/extension of the limbs and core that will occur during training or competition (Zink, 2014). Moreover, greyhound racing influences canine joint angles with a higher amount of flexion. The explicit reason of improved joint ROM is unknown; that said, enhanced ROM has certainly been associated with enriched SL and athletic performance specifically in equine jumping and dressage disciplines (Wei-Cheng Lin *et al.,* 2020).

Correspondingly, Stewart & Sleivert, (1998) highlighted that the intensity of different warmup techniques has no effect on ROM or SL as all groups, with omission of the control group, accustomed a substantial enhancement in ROM. These investigations were complementary which ratifies results and suggests that despite limited exploration in this field, a warmup prior to exercise would positively improve performance by enhancing ROM and SL and permitting improved muscular recruitment. The results and allegations from this investigation may narrate to those of Takeuchi *et al.,* (2021); Stewart & Sleivert, (1998) with ROM and SL being influenced by warmup.

Colborne *et al.,* (2006) noted an increase in trotting velocity in greyhounds does not change the general work and function of different joints of the pelvic limb, although local burst amplitudes throughout the stance phase escalate additionally. The rotary gallop is the most common gait for the racing greyhound but the most fatiguing (Eager & Walker, 2016). This is a double suspensory gait. The trailing hindlimb contacts the ground seconds ahead of the leading hindlimb (Bertram & Gutmann, 2009; Hayati *et al.,* 2021). Therefore, this provides pelvic bipedal support, propelling the dog cranially pursued by the suspension phase fully extending the spine and the forelimbs extending in front, allowing the trailing forelimb that is ipsilateral with the leading hindlimb contacting the ground, abruptly trailed by the leading forelimb (Walter & Carrier, 2007; Bertram & Gutmann, 2009; Hayati *et al.,* 2019).

Not to mention, galloping around the racetrack bend has increased ground forces than galloping on the straight section indicating an extensive force is enforced on limbs as a result of centrifugal force (Hayati *et al.,* 2018). That said Hayati *et al.,* (2021) illustrates that although the various elements of the gait cycle have been dignified, a deeper investigation at the recurrence plots and their quantification analysis might acknowledge variations in foot pattern. Additionally, the flight phase has yet to be fully hypothesized, for which possibly requires an increased sampling rate and more strides captured would be required for this study (Hayati *et al.,* 2021). According to Usherwood & Wilson (2005) when greyhounds enter a tight bend, they do not alter their foot-contact timings, therefore, must withstand a 65% raise in limb forces, highlighting that the muscles providing power are regularly isolated from the anatomical mechanisms supporting their weight, hence the high rate of tarsal fractures. Pure acceleration is strength dependant therefore, attaining maximum speed in human studies is the extent of force an athlete can administer on each foot strike, also contact time is a contributing factor (Parisi, 2022).

In general, the importance of having muscle groups warmed up is evident throughout literature as common injuries occur from extreme sports, although restrictions of implementing these warmups before racing has its limitations due to kennelling rules. Thus, movement strategy, training, lifestyle, and diet creates speed in a complex multidimensional approach (Parisi, 2022). Granting, continuous improvements in canine gait kinematics is ongoing shaping information on joint and limb patterns, muscle work and power (Mucha & Bockstahler, 2019).

Overall, optimal speed comes from a symphony of biological systems firing harmonically in unison which will result in maximum ROM, SL, and performance (Parisi, 2022).

2.1.1 Aim

- The aim of this experiment was to measure the effect of different warmup techniques prior to exercise on the kinematics of racing greyhounds.

2.1.2 Objectives

- Devise a question and implement a search strategy defining relevant papers.
- Conduct a study measuring racing greyhound dynamic ROM, SL, and time, after the completion of a variety of warmup techniques (with a control).
- Conduct statistical analysis on results found and determine the significance of findings.
- To understand and investigate findings relating to warmup techniques before exercise in racing greyhounds and measure how to implement physiotherapeutic protocols within greyhound racing.

2.1.3 Hypothesis (H1)

H(1.1): Warmup before exercise will have a significant effect on the racing greyhound dynamic range of motion.

H(1.2): Warmup before exercise will have a significant effect on time of the racing greyhound.

H(1.3): Warmup before exercise will have a significant effect on stride length of the racing greyhound.

H(1.4): Warmup before exercise will have a significant effect on limb kinematics of the racing greyhound.

2.1.4 Null Hypothesis (H0)

H(0.1): Warmup before exercise will have no significant effect on racing greyhound dynamic range of motion.

H(0.2): Warmup before exercise will have no significant effect on time of the racing greyhound.

H(0.3): Warmup before exercise will have no significant effect on stride length of the racing greyhound.

H(0.4): Warmup before exercise will have no significant effect on limb kinematics of the racing greyhound.

3. Methodology

3.1 Ethical Considerations

This investigation adhered to the guidelines defined in the Animals (Scientific Procedures Act) 1986 and was accepted by the Writtle College Animal Welfare and Ethics Committee (protocol number: 98383622/2024). Owner consent and use of facilities was also granted prior to starting the investigation. Each subject encountered a comprehensive examination to determine any signs of lameness prior to the investigation, as the ability to identify a population similar in age over a fixed period is critical for data collection (O'Neill *et al.,* 2014). A Microsoft teams video call was undertaken with Jade Terry (supervisor) each morning of the trial to ensure each subject was eligible to part take in the study, she assessed each subject statically/dynamically for any signs of lameness (Plate 1). The subjects were provided with fresh drinking water immediately after each gallop, were given regular warmup/cool down periods, and were constantly supervised during the study. If any subject showed signs of lameness/pain, they were instantly withdrawn from the investigation. Each subject is regularly galloped on this specific gallop to help build fitness, and focus on stamina, strength, and proprioception, like a study conducted by Farr *et al.,* (2020), therefore this investigation coincided with their normal training regime. The ground conditions were assessed by the owner each morning of data collection to ensure the gallop was in high standard condition and safe for use. The best decisions were made when priorities were distinctly detailed between all those involved in the decisions chosen (Lovell, 2013; Belshaw, 2017).

***Plate 1:** All subjects lined up for static and dynamic assessment with supervisor – authors own (2024).*

3.2 Subjects

Taking animal ethics into consideration, the 'resource equation' method was utilised to determine the minimum sample size required, whilst being in a position to portray statistically significant results (Arifin and Zahiruddin, 2017). Therefore, the sample concluded of six clinically healthy, sound racing greyhounds of the same litter, hence, all the exact same age, four females and two males.

All subjects were of a healthy body condition score (BCS) shown in (Table 2). Subjects were collectively gathered from a reputable licensed and successful breeding and training kennels. Owner consent was required prior to enrolment. Additionally, each subject had been born, bred, and schooled on the premises and housed in side-by-side kennels with similar daily routines, consisting of walking/swimming/galloping/trialling, and racing. Moreover, highlighting a high degree of fitness levels amongst the group. Moreover, the subjects were kept in their usual kennels (Plate 2) to ensure correct body temperature was kept persistent across each subject. After each gallop, the subject was returned to its usual kennel, to allow them cool down and rest between data collection. Thus, the frequency of data collection allowed the subjects to be kept in their normal routine.

Table 2: *Details of the individual subjects, including age, sex, and body condition score.*

Dog	**Age**	**Sex**	**BCS (1-5)**
1	17 months	F	3
2	17 months	F	2
3	17 months	M	4
4	17 months	F	3
5	17 months	M	3
6	17 months	F	3

***Plate 2**: Subject 3 returned to kennel after data collection – (authors own, 2024).*

3.3 Experimental Design

A crossover arrangement was used for the study, whereby each subject obtained three various warmup techniques during the period of the trial, no warmup acting as the control. This arrangement disqualifies between-subject variation as the warmup techniques are explored within the same subject (Mills *et al.,* 2009). The subject and treatment order (Table 3) was prearranged and randomised by utilising a random selection generator (wheelofnames.com), therefore, this reduced any exposure of bias and any sequence of a carryover effect (Page *et al.,* 2022). Also, the subject's number (1-6) was randomly assigned before arrival, using the same random selection generator. Thus, each warmup was implemented by the same individual. Moreover, after each gallop, the subject was returned to its kennel after a cool-down period consisting of a 5–10-minute global massage and a 5-minute slow walk to ensure normal resting heart rate. Thus, each foot was washed/dried, and subjects were then placed back in their kennels to rest for the remainder of the day before the next warmup technique took place two days later. According to Vargas *et al.,* (2018); Vargas *et al.,* (2020), 30 minutes has been noted as plentiful and satisfactory at permitting body temperature to recover back to baseline level post exercise.

Interventions	Day 1	Day 2	Day 3	Day 4
Heat	1 & 2	3 & 5	4	6
Massage	6	2	1	3, 4 & 5
Trot	3 & 4	1 & 6	5	2
No warmup	5	4	2, 3 & 6	1

Table 3: *Subject and treatment order during data collection.*

3.4 Warmup Techniques

Warmup techniques consisted of heat, massage, trot, and no warmup, which served as the control. As a result of this, each subject was their own control reducing the risk and influence of error. Furthermore, to eradicate further misconception, each warmup was performed by same individual (Farr *et al.,* 2020), a qualified veterinary physiotherapist/hydro therapist.

Heat was utilised on both hindlimbs targeting the *m. biceps femoris* the largest hamstring muscle which obtains maximum force and power of the hindlimb (Williams *et al.,* 2008). This consisted of 10 minutes evenly split in to two 5 minutes to target each limb evenly. Heat was chosen using microwaveable heat packs wrapped in a towel to ensure it was the correct temperature preventing direct contact with the skin (Heinrichs, 2004). Again, the subjects remained standing square throughout applying heat so that each limb was readily available (plate 3:1). Furthermore, this was implemented directly before each subjected was galloped to ensure the subject did not cool down.

To continue, massage was 10 minutes in total which consisted of effleurage/tapotement to the *m. biceps femoris* of the hindlimbs bilaterally. The 10 minutes was divided into two 5 minutes to ensure both hindlimbs received equal massage. This helped ensure data collection strategies had an influence on the level of results validity (Evans & Crawford, 2000). Tapotement was used to stimulate the muscle by using cupping/hacking techniques. The subject continued standing during the massage so that each hindlimb was easily available (Plate 3:2). This was implemented immediately before each subject was galloped.

Trot consisted of a steady pace for 10 minutes. Each subject was exercised outside to assure acceptable space, and all were exercised on the same levelled tarmac. Each subject was exercised using the same lead to control the gait of each subject (Plate 3:3).

For the control, the subjects were walked from their kennel straight to the gallop for data collection (Plate 3:4). Each day before data collection, the author galloped a subject not included in the trial to ensure that everything ran smoothly for the data collection. This ensured that the timers/lure/setup was all working efficiently to prevent any issues throughout the data collection and to make any amendments if needed.

Plate 3: *Subject's receiving different warmup techniques prior to being exercised on the gallop. (1. Heat, 2. Massage, 3. Trot, 4. No warmup) – (authors own, 2024).*

3.5 Data Collection

The experiment was conducted on the premises of Ballymore kennels, a training facility located in Kildare, Ireland. Over four days, data was collected for 6 greyhounds each day: January 3rd, 5th, 7th, and 9th. Six racing greyhounds were used to ensure accurate results were formed, to reduce stress/complications of big volume. As the data collection research took place over four days, the set up and methodological procedures remained the same and consistent each day.

Once each warmup technique was implemented, 10 reflective markers (10 mm diameter) using zinc oxide were located on the right-hand side of each subject (Plate 4), on anatomical locations commonly used in kinematic analysis, although slight variations in the breed occurred, markers were precisely allocated (Allen *et al.,* 1994; DeCamp *et al.,* 1993, p.1993; DeCamp *et al.,* 1996; Goldner *et al.,* 2015; Carr and Dycus, 2016). The joints being analysed consisted of the glenohumeral joint, the elbow joint, the carpal joint, the coxofemoral joint, the stifle joint and the tarsal joint, like the study by Bliss *et al.,* (2022). Therefore, markers were located on the coat over the dorsal aspect of the scapula, greater tubercle of the humerus, lateral epicondyle of the humerus, ulnar styloid process and distolateral aspect of the fifth metacarpal bone. On the pelvic limb, zinc oxide was located on the iliac crest, greater trochanter of the femur, lateral epicondyle of the femur, lateral malleolus of the fibula and distolateral aspect of the fifth metatarsal bone. Zinc oxide was chosen rather than the stick-on reflective markers as it was concluded that stick on reflective markers would fall off when subjects are in full flight at high speed in gallop (Hottinger *et al.,* 1996; DeCamp, 1997; Andrada *et al.,* 2017). This way, zinc oxide could be washed off afterwards and reapplied ach day on the same bony landmark ensuring consistency. Also, consistency of marker placement was considered, the accuracy of calibration, and the alteration in velocity when defining kinematic gait analysis (McGinley *et al.,* 2009; Hobbs *et al.,* 2010). Due to the grass on the gallop being wet, zinc oxide, was slightly washed off on the lateral aspect of metacarpal V and lateral aspect of metatarsal V. Therefore, it was difficult to see these bony landmarks on the videos. As data collection continued, the decision was made to not place the zinc oxide on these two areas and to manually track instead, to prevent complications. Moreover, when it came to video analysis these two bony landmarks were manually tracked using Quintic biomechanics software to ensure accurate readings.

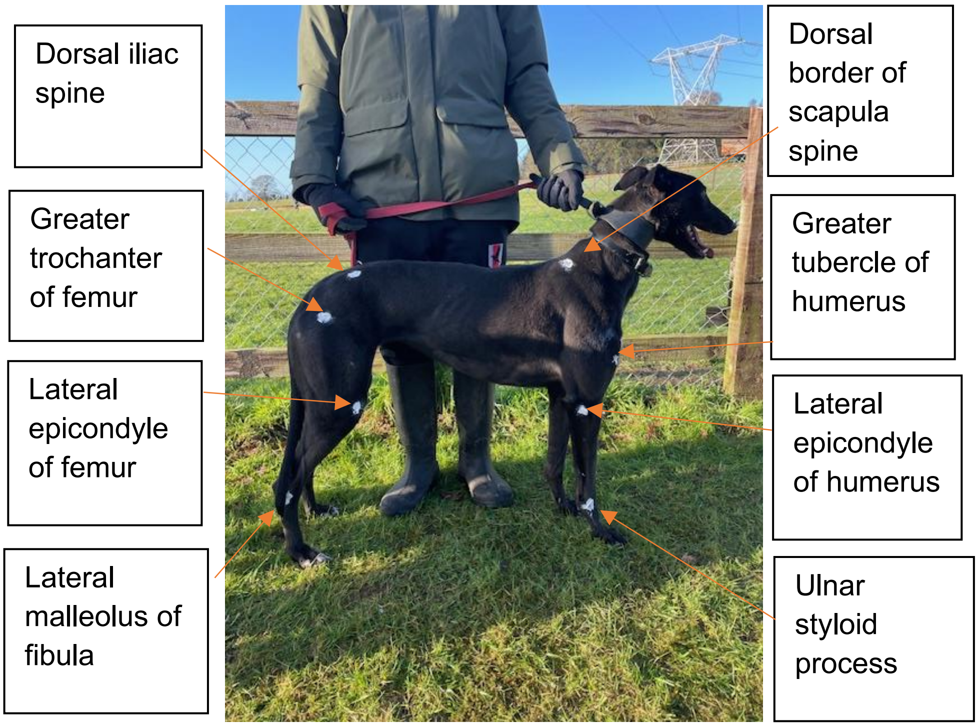


Plate 4: *Reflective markers placed on the subject seconds before being exercised on the gallop. Metacarpal and metatarsal V not marked due to visibility issue with tracking -(authors own, 2024).*

To prevent the subjects from beginning to cool-down during marker placement, the zinc oxide was readily prepared and placed on immediately after warmup, seconds before each subject was released on the gallop. Thus, to maintain accuracy of repeatability of marker placement, the markers were enforced by the same individual each day.

Three video cameras (iPhone 14) were utilised to document the data using 2D analysis, at a rate of 240 frames per second to enhance data efficacy (Ringaby & Forssén, 2012; Ghadiyaram *et al.,* 2017). Each camera was mounted on a tripod, exactly 3 m away from the runway, each evenly spaced along the gallop (116.67m between each tripod station) which was 350 meters total. Initially, 5-6 strides were to be captured at each station, but due to the tripods being placed further away, it made it difficult to see all markers due to the high speed at which the subjects were moving. Therefore, one stride was chosen for efficacy. Station 1 (start station) was located at the start of the gallop where subjects were taking off, station 2 (middle station) was halfway up the gallop where subjects were mid-flight, and station 3 (finish station) was at the top of the gallop where subjects were slowing down. Also, the same individuals recorded at each station each day for consistency. This ensured accurate SL was captured at the same level at each station. Each individual started recording once the lure started moving for accuracy between videos.

The cameras recorded the subjects from the right-side lateral aspect, (see Plate 5), to accurately track the markers at 1.5 speed slow motion (Ringaby & Forssén, 2014). Storage was created prior on each iPhone to capture the volume of videos and to prevent any issues. Thus, old files/documents/images were deleted or added to iCloud on each iPhone to prevent storage issues ensuring the videoing was efficient (France *et al.,* 2013). This ensured memory storage was created and videos were backed up to the iCloud system.

Plate 5: *The tripod station set up to record the subjects from a lateral aspect, right side station 1 (start), station 2 (middle) and station 3 (finish) – (authors own, 2024).*

Each subject was walked at their preferred gait to the bottom of the gallop on a lead, in preparation for take-off. To diminish error/enhance accuracy of results, the same handler was used throughout the study as well as the same slip lead to create an easy release at the start (Disman *et al.,* 2017). Each subject was timed using a built-in timing system implemented on the gallop to accurately time each subject. Built in beams are placed on the gallop, one set at take-off and the other near the finish to accurately time each subject's performance (Plate 6). This system was fitted by Timing Ireland, a reputable Irish timing company. The times of each subject were noted on a handheld device, printed, and recorded each day (Plate 7:1). A lure was used to encourage subjects to give full efforts when galloped each day, which was controlled by the same individual to maintain accuracy of speed and distance (Plate 7:2). Although, at times the lure did move off the path, causing some of the subjects to drift off slightly to one side which may have affected their overall time performance, but markers remained clear in each video at each station.

Plate 6: *Built in timing system with beams placed on the gallop, one set at take-off (start) and one set when slowing down (finish) to accurately start the time of each subject's performance – (authors own 2024).*

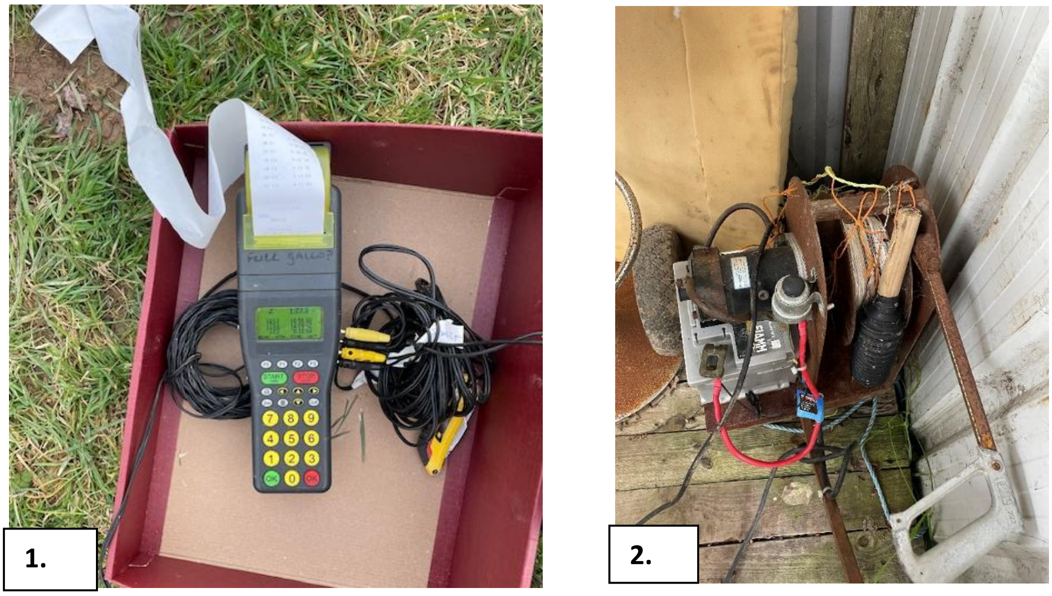


Plate 7: *(1) Handheld timing device which automatically prints off times of each subject once passed the second set of beams and (2) Lure used throughout data collection – (authors own, 2024).*

3.6 Data Analysis

Once all the video recordings were collected and downloaded onto Quintic biomechanics software using a remote connection, analysis of each video was undertaken (see results section 4). Furthermore, for each video station, one single stride was used for interpretation, the stride of choice varied depending on the straightness of the subject, consistency of the gait, and clarity of the retro-reflective markers. The kinematic software identified the markers and designated orthogonal values regarding these points within each frame (Gillette & Angle, 2008). This permits the software to determine angular movement of segments over a certain distance. Furthermore, SL (m) was measured using foot placement, while auto-tracking was implemented to assemble figures on ROM (°) at station 1,2 and 3 of the chosen joints. Time performance was noted of each subject also. All figures noted were placed chronologically in a Microsoft Office Excel 365 ProPlus (Microsoft Corporation, Redmond, Washington) spreadsheet to calculate the mean of all measurements from the repetitions at each station. From there, data was transferred to SPSS for statistical analysis.

3.7 Statistical Analysis

SPSS Statistics software (version 29, IBM Corporation, Armonk, New York, USA) was used for statistical analysis. Normality was assessed using the Shapiro-Wilk test, by inspection of a boxplot. Moreover, if data was shown to be normally distributed, one-way repeated measures ANOVA was organised to distinguish if warmup had a statistically significant influence on the parameters outlined. On the other hand, if the data was not normally distributed, a Friedman test was conducted to decipher if statistical significance was evident. Additional details of statistical analysis are outlined in the results (section 4).

4. Results

4.1 SL – Sation 1

SL was broken up into three stations, Start (station 1) Middle (station 2), and Finish (station 3). The analysis in this section is exclusively that of the "start" station, further tests on the Middle and Finish stations were carried out in sections (4.1.1 & 4.1.2).

There were no outliers in the data, as assessed by analysis of a boxplot. SL was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test ($p > .05$). A one-way repeated measures ANOVA was organised to regulate if there were statistically significant variations in SL (station 1) with the use of various warmup interventions.

Data are mean ± standard deviation. SL at station 1 decreased from 0.7317± 0.45° with no warmup to 0.6833± 0.23° with massage and decreased more to 0.5833± 0.29° with trot and finally decreased to 0.5783± 0.27° with heat. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, $x^2(5) = 8.390$, $p = 0.148$. On further analysis of the pairwise comparison of each warmup technique, it was observed that there were no significant differences (see Figure 3) amid the warmup techniques ($P=1.0$), $F(3, 15) = 0.380$, $P< 0.769$. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant $p>0.05$.

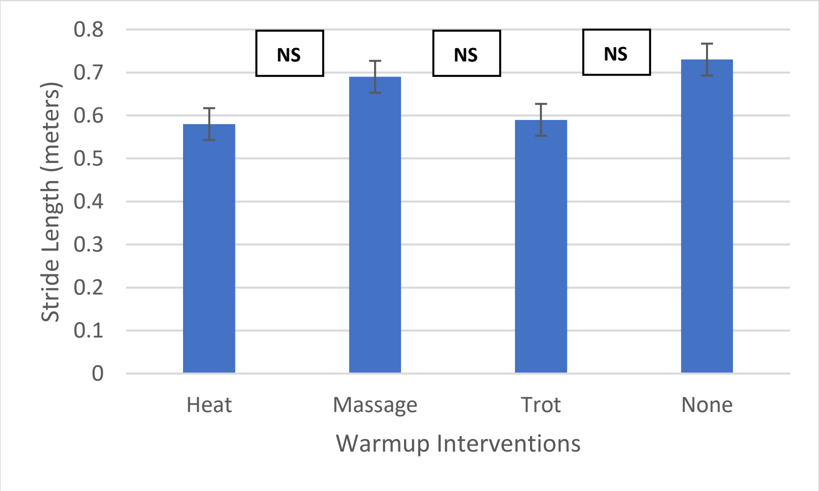


Figure 3: *The effect of heat, massage, trot, and no warmup on mean SL station 1 (meters). Error bars serve as standard deviation (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.1.1 SL – Station 2

An initial normality test was carried out on station 2 and it was noted that SL was not normally dispersed with each warmup, portraying nonparametric data unlike station 1 & 3, as adjourned by Shapiro-Wilk test ($p < .05$).

A Friedman test was then carried out to distinguish if there were variations in SL with four different warmup techniques. Pairwise comparisons were performed (SPSS Statistics, 2012) with a Bonferroni correction for multiple comparisons with none detected. SL was not statistically significantly different (see Figure 4) with the various warmups, X^2 (3) = 2.200, p = 0.532.

Post hoc analysis portrayed no statistically significant variations in SL between heat (mdn = 4.7200), massage (mdn = 3.5500), trot (mdn = 4.3400) and no warmup (mdn = 3.1050) (p =1.000).

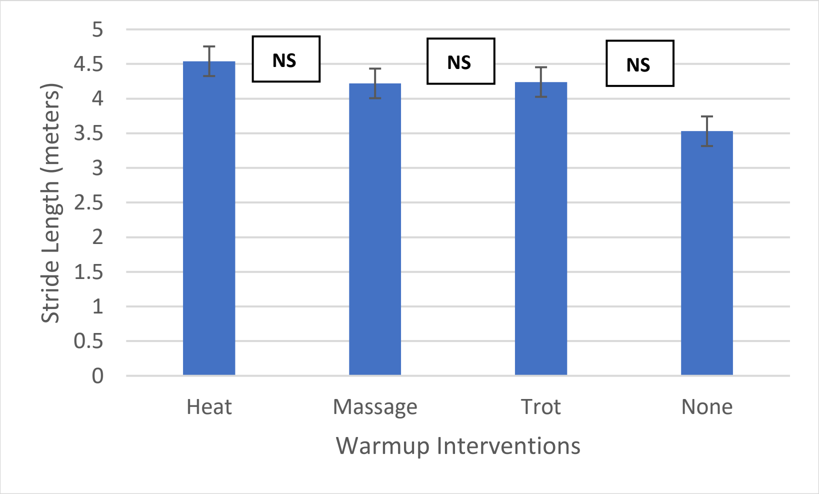


Figure 4: *The effect of heat, massage, trot, and no warmup on mean SL station 2 (meters). Error bars serve as standard deviation (n=4). No statistical significance (NS) is recorded (p<0.05) by Friedman's test.*

4.1.2 SL – Station 3

As with station 1, a one-way repeated measures ANOVA was organised to decipher whether there were statistically significant alterations in SL (station 3), with the use of four various warm up techniques. There were no outliers in the data, as approved by examination of a boxplot. SL was normally distributed at each warmup, as assessed by Shapiro-Wilk test ($p > .05$). Data are mean ± standard deviation. SL decreased from 3.32 ± 1.12° with heat to 3.25 ± 1.24° with massage and decreased further to 3.03 ± 1.11° with no warmup and finally 2.62 ± 0.84° with trot. Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated, $\chi2(5) = 7.303$, $p = 0.498$. On further analysis of the pairwise comparison of each warmup technique, it was observed that there were no significant differences (see Figure 5) between the warmup techniques ($P=1.0$), $F(3, 15) = 0.545$, $P < 0.659$. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant $p>0.05$.

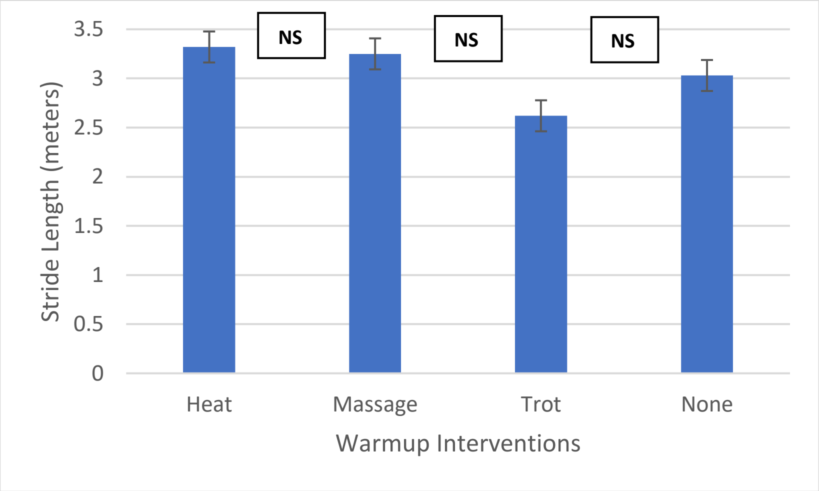


Figure 5: *The effect of heat, massage, trot, and no warmup on mean SL station 3 (meters). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.1.3 Summary of SL

SL was normally distributed at each warmup, as assessed by Shapiro-Wilk test (p >.05) for station 1 & 3 and distributed nonnormally for station 2 (p < .05). This led to conducting a one-way repeated measure ANOVA test for station 1 & 3 (sections x), and a Friedmans test for station 2 (section x). Each phase of SL (station 1,2 & 3) was looked at separately to decipher if warmup had a significance on subjects at each phase of taking off, mid-flight and slowing down. From the analysis carried out it can be determined that warmup techniques have no statistically significant impact on SL across all stations. Furthermore, each SL was also grouped together (across station 1, 2 & 3) in order to assess SL against each warmup intervention to view results as a whole, minimal differences were noted although not statistically significant amid any SL over the entire gallop.

4.2 Glenohumeral ROM – Station 1

ROM was broken up into three stations, Start (station 1) Middle (station 2), and Finish (station 3). The analysis in this section is exclusively that of the "start" station for shoulder ROM, further tests on the Middle and Finish stations were carried out in sections (4.2.1 & 4.2.2).

Shoulder ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was organised to portray if there were statistically significant variations in shoulder ROM (station 1) with the use of four variations of warmup interventions.

Data are mean ± standard deviation. Shoulder ROM decreased from 68.1500 ± 21.25° with massage, to 67.5050 ± 24.17° with no warmup, decreasing further to 59.0950 ± 22.85° with heat, and finally decreased further to 45.9067 ± 8.84° with trot. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 5.946, p =0.326. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 6) between the warmup techniques, F (3, 15) = 1.314, P< 0.307. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

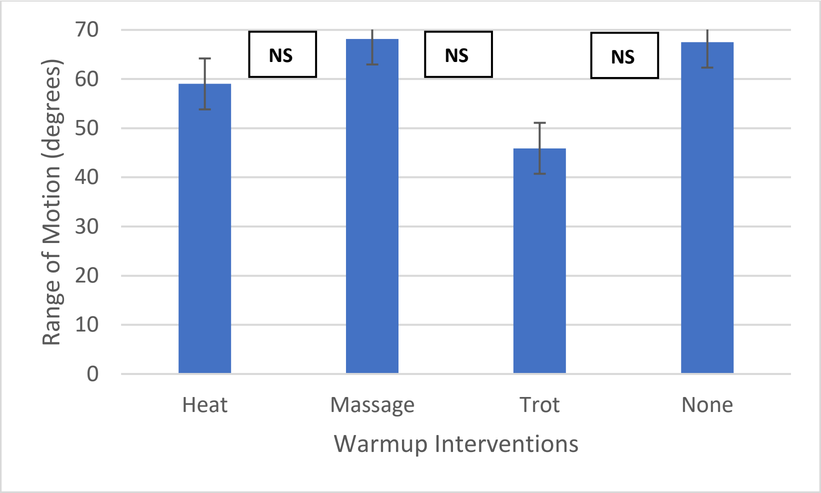


Figure 6: *The effect of heat, massage, trot, and no warmup on mean shoulder ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.2.1 Glenohumeral ROM – Station 2

An initial normality test was carried out on middle (station 2) and it was noted that shoulder ROM was not normally dispersed with each warmup, portraying nonparametric data unlike station 1 & 3, as adjourned by Shapiro-Wilk test ($p < .05$). A Friedmans test was conducted to highlight if there were statistically significant variations in shoulder ROM (station 2) with the use of four different warmup interventions.

Pairwise comparisons were conducted (SPSS Statistics, 2012) with a Bonferroni correction for multiple comparisons, with none outlined. Shoulder ROM was not statistically significantly different (see Figure 7) with the different warmups, X^2 (3) = 0.400, p = 0.940. Post hoc analysis portrayed no statistically significant variations in Shoulder ROM between heat (mdn = 90.70°), massage (mdn = 92.17°), trot (mdn = 86.85°) and no warmup (mdn = 90.19°) (p =1.000).

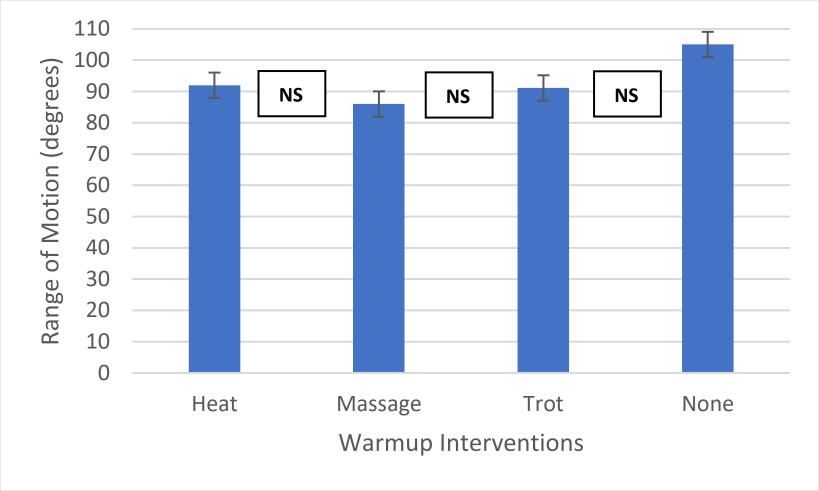


Figure 7: *The effect of heat, massage, trot, and no warmup on mean shoulder ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p<0.05) by Friedman's test.*

4.2.2 Glenohumeral ROM- Station 3

Shoulder ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot.

A one-way repeated measures ANOVA was organised to portray if there were statistically significant variations in shoulder ROM (station 3) with the use of four variations of warmup interventions.

Data are mean ± standard deviation. Shoulder ROM decreased from 108.6750 ± 65.53° with no warmup, to 105.9033 ± 67.54° with heat, decreasing further to 66.7250 ± 13.21° with massage, and finally decreased further to 55.1850 ± 13.47° with trot. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 16.160, p =0.008. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 8) between the warmup techniques, F (3, 15) = 1.545, P< 0.244. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

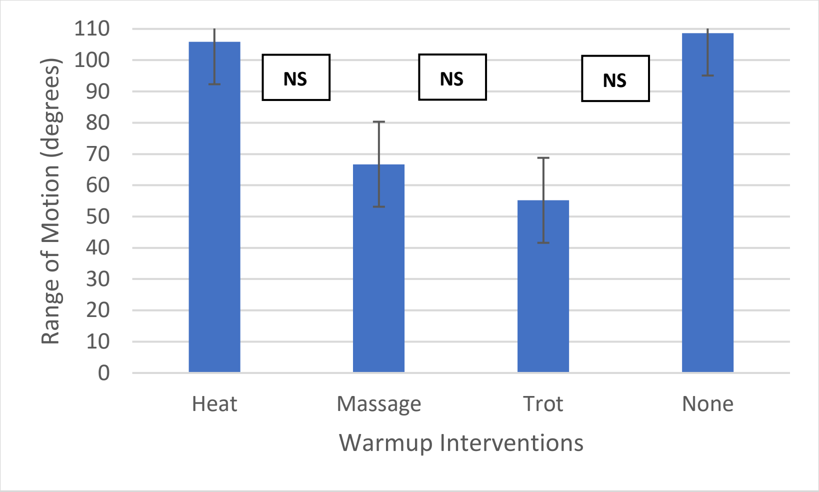


Figure 8: *The effect of heat, massage, trot, and no warmup on mean shoulder ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.3 Elbow ROM- Station 1

Elbow ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was organised to highlight if there were statistically significant variations in elbow ROM (station 1) with the use of four different warmup interventions.

Data are mean ± standard deviation. Elbow ROM decreased from 88.1183±10.83° with massage, to 85.2583±15.30° with trot, decreasing further to 71.2583±31.15° with no warmup and finally decreased further to 70.5250±26.19 with heat. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 5.624, p =0.359. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 9) between the warmup techniques, F (3, 15) = 0.984, P< 0.307. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.427.

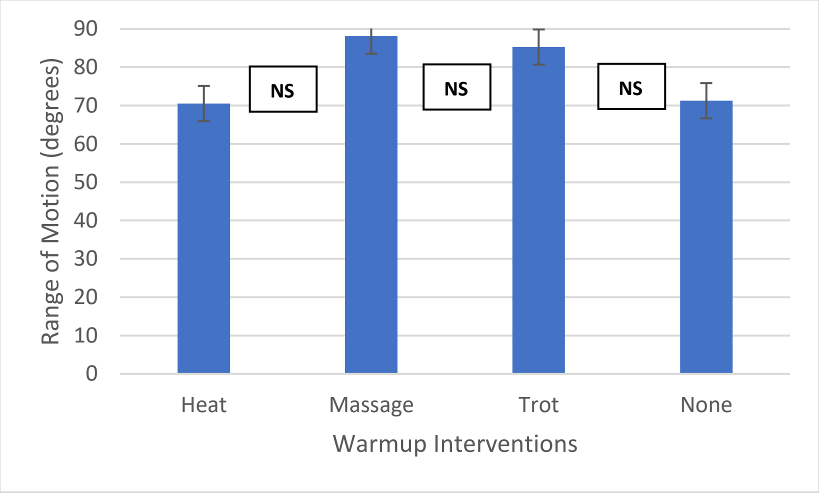


***Figure 9:** The effect of heat, massage, trot, and no warmup on mean elbow ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.3.1 Elbow ROM- Station 2

An initial normality test was carried out on middle (station 2) and it was considered that elbow ROM was not normally dispersed with each warmup, portraying nonparametric data unlike station 1 & 3, as adjourned by Shapiro-Wilk test ($p < .05$). A Friedmans test was conducted to highlight if there were statistically significant variations in elbow ROM (station 2) with the use of four various warmup interventions.

Pairwise comparisons were conducted (SPSS Statistics, 2012) with a Bonferroni correction for multiple comparisons, with none outlined. Elbow ROM was not statistically significantly different (see Figure 10) with the different warmups, $X^2 (3) = 7.400$, $p = 0.60$. Post hoc analysis portrayed no statistically significant variations in elbow ROM between heat (mdn = 109.12°), massage (mdn = 92.32°), trot (mdn = 111.47°) and no warmup (mdn = 126.86°).

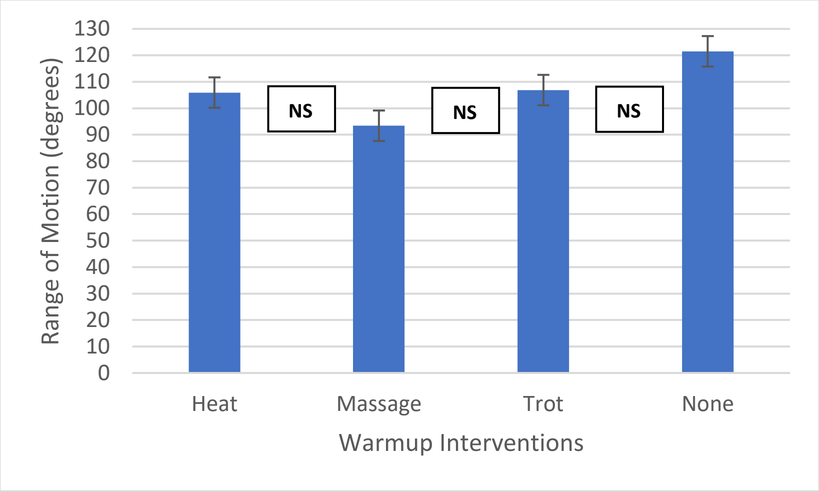


Figure 10: *The effect of heat, massage, trot, and no warmup on mean shoulder ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p<0.05) by Friedman's test.*

4.3.2 Elbow ROM- Station 3

Elbow ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test ($p > .05$). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was organised to portray if there were statistically significant variations in elbow ROM (station 3) with the use of four various warmup interventions.

Data are mean ± standard deviation. Elbow ROM decreased from 137.6317±17.99° with massage, to 136.1083±14.33° with trot, decreasing further to 132.7883±21.27° with no warmup and finally decreased further to 126.0050±21.26° with heat. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 8.666, p =0.135. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 11) between the warmup techniques, F (3, 15) = 0.483, P< 0.699. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant $p>0.05$.

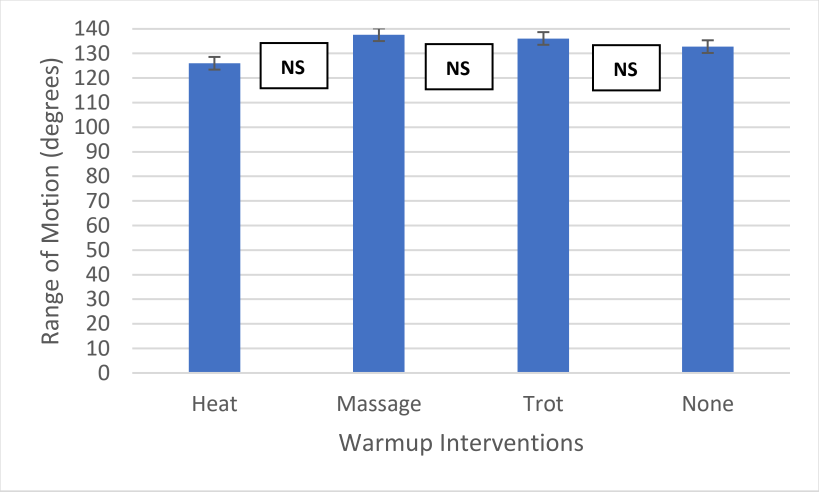


Figure 11: *The effect of heat, massage, trot, and no warmup on mean elbow ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.4 Carpal ROM -Station 1

Carpal ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was organised to portray if there were statistically significant variations in carpal ROM (station 1) with the use of four various warmup interventions.

Data are mean ± standard deviation. Carpal ROM decreased from 152.4633±33.05° with massage, to 146.6933±46.44° with trot, decreasing further to 130.3600±32.86° with heat, and finally decreased to 125.1533±34.68° with no warmup. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 4.726, p =0.464. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 12) between the warmup techniques, F (3, 15)

= 0.865, P< 0.481. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

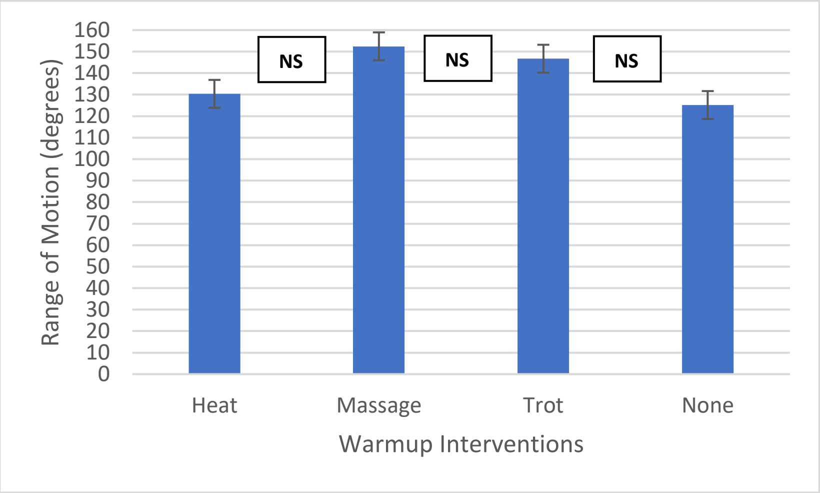


Figure 12: *The effect of heat, massage, trot, and no warmup on mean carpal ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.4.1 Carpal ROM -Station 2

Carpal ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was performed to portray if there were statistically significant variations in carpal ROM (station 2) with the use of four various warmup interventions.

Data are mean ± standard deviation. Carpal ROM decreased from 125.4400±23.73° with trot, to 116.4450±25.61° with massage, decreasing further to 112.8150±42.77° with no warmup, and finally decreased to 112.6283±34.71° with heat. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 5.117, p =0.416. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 13) between the warmup techniques, F (3, 15) = 0.192, P< 0.900. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

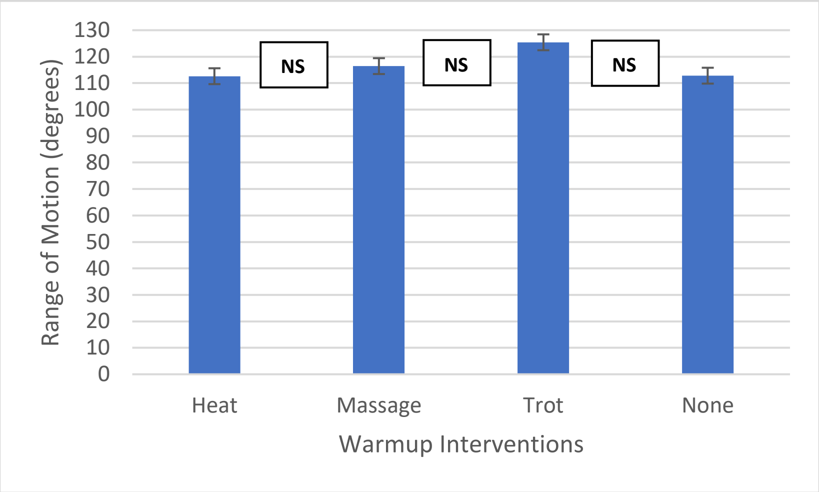


Figure 13: *The effect of heat, massage, trot, and no warmup on mean carpal ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.4.2 Carpal ROM- Station 3

Carpal ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was performed to portray if there were statistically significant variations in carpal ROM (station 3) with the use of four various warmup interventions.

Data are mean ± standard deviation. Carpal ROM decreased from 132.6033±33.97° with trot, to 123.9617±26.71° with heat, decreasing further to 117.9283±26.69° with no warmup, and finally decreased to 109.4267±27.61° with massage. Mauchly’s test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) =

6.239, p =0.298. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 14) between the warmup techniques, F (3, 15) = 0.713, P< 0.559. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

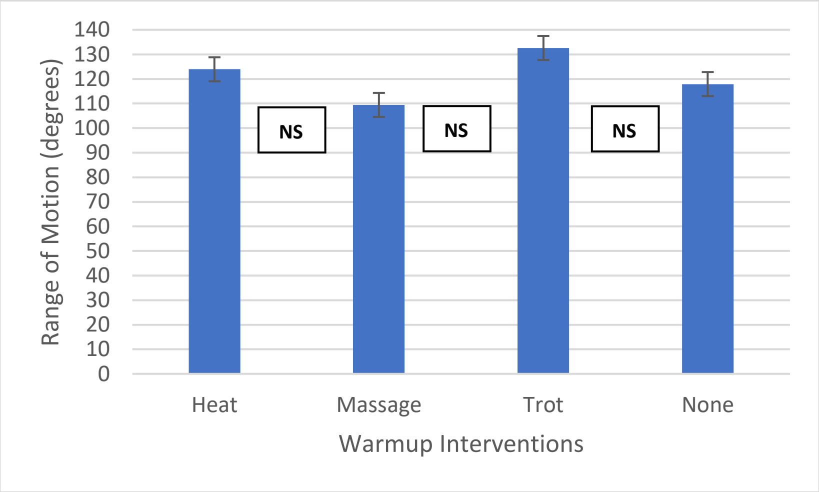


Figure 14: *The effect of heat, massage, trot, and no warmup on mean carpal ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.5 Coxofemoral ROM- Station 1

Coxofemoral ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was performed to portray if there were statistically significant variations in coxofemoral ROM (station 1) with the use of four various warmup interventions.

Data are mean ± standard deviation. Coxofemoral ROM decreased from 82.6700 ± 14.04° with no warmup, to 75.7033 ± 4.95° with massage, decreasing further to 73.5300 ± 5.97° with trot, and finally decreased further to

52.6067 ± 29.35° with heat. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 16.988, p =0.006. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 15) between the warmup techniques, F (3, 15) = 3.133, P< 0.57. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

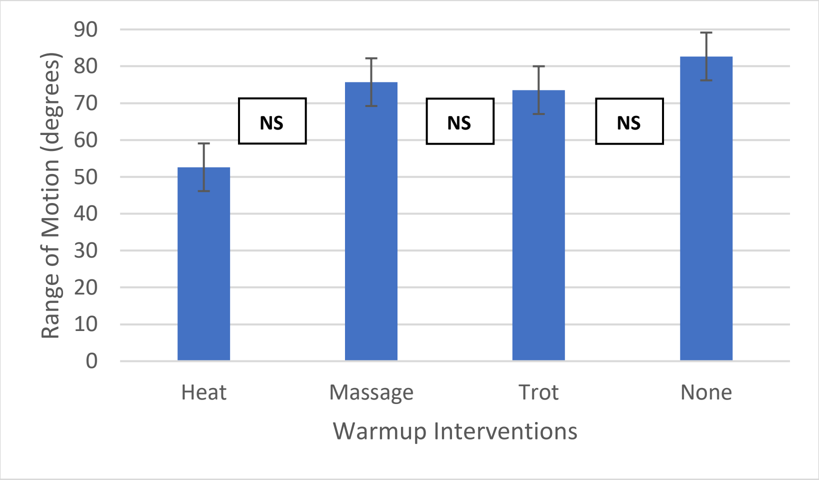


Figure 15: *The effect of heat, massage, trot, and no warmup on mean* coxofemoral *ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.5.1 Coxofemoral ROM-Station 2

Coxofemoral ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot.

A one-way repeated measures ANOVA was performed to portray if there were statistically significant variations in coxofemoral ROM (station 2) with the use of four various warmup interventions.

Data are mean ± standard deviation. Coxofemoral ROM decreased from 102.9383 ± 13.97° with trot, to 97.5967 ± 20.68° with heat, decreasing further to 88.4433 ± 22.35° with massage, and finally decreased further to 86.2650± 11.36° with no warmup. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 5.030, p =0.426. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 16) between the warmup techniques, F (3, 15) = 1.005, P< 0.418. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

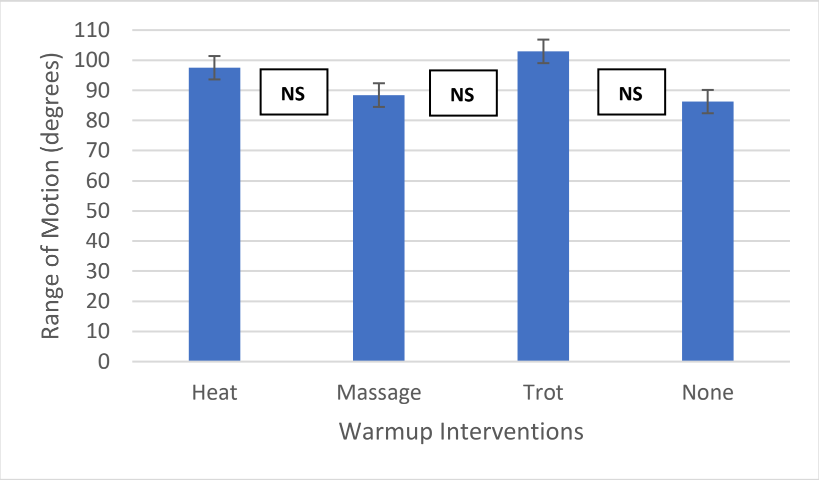


Figure 16: *The effect of heat, massage, trot, and no warmup on mean* coxofemoral *ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.5.2 Coxofemoral ROM- Station 3

Coxofemoral ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was performed to portray if there were statistically significant variations in coxofemoral ROM (station 3) with the use of four various warmup interventions.

Data are mean ± standard deviation. Coxofemoral ROM decreased from 87.4133 ± 35.01° with massage, to 83.1750 ± 22.14° with no warmup, decreasing further to 82.3833 ± 15.21° with heat, and finally decreased further to 81.5550 ± 13.11° with trot. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 7.463, p =0.202. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 17) between the warmup techniques, F (3, 15) = 0.078, P< 0.971. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

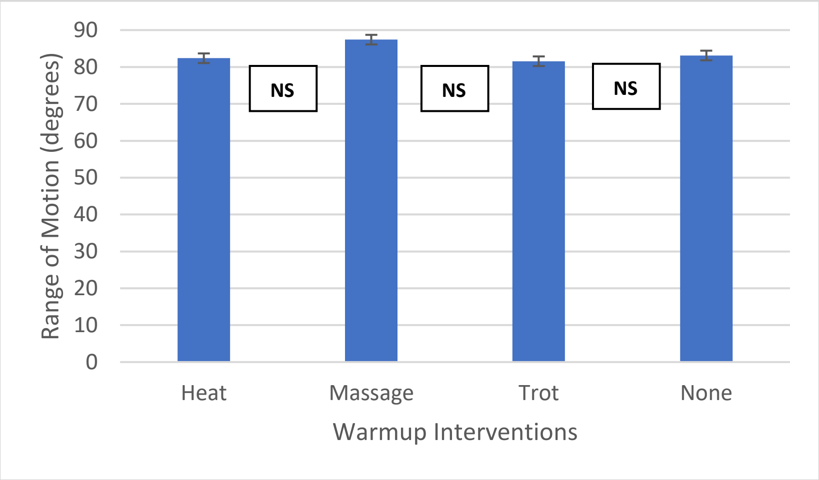


Figure 17: *The effect of heat, massage, trot, and no warmup on mean* coxofemoral *ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.6 Stifle ROM- Station 1

Stifle ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was performed to portray if there were statistically significant variations in stifle ROM (station 1) with the use of four various warmup interventions.

Data are mean ± standard deviation. Stifle ROM decreased from 73.2517 ± 23.62° with no warmup, to 59.5383 ± 21.68° with massage, decreasing further to 52.1383 ± 13.00° with trot, and finally decreased further to 51.7267 ± 22.37° with heat. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 2.216, p =0.824. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 18) between the warmup techniques, F (3, 15) = 1.167, P< 0.355. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

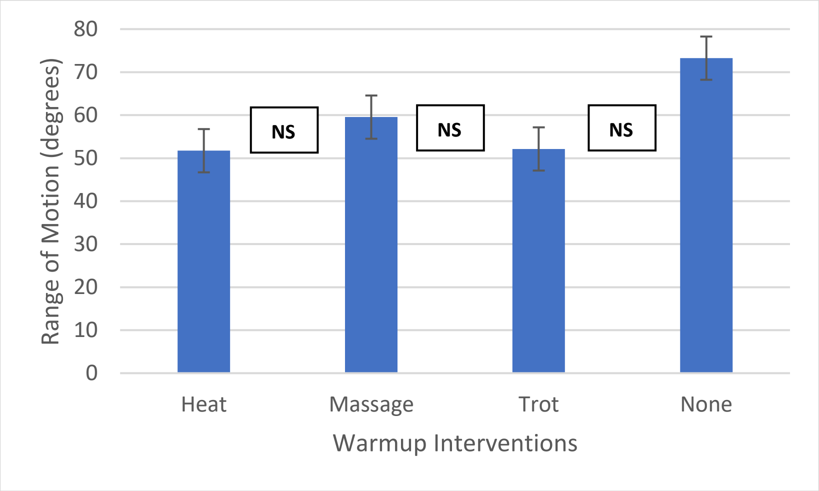


Figure 18: *The effect of heat, massage, trot, and no warmup on mean stifle ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.6.1 Stifle ROM-Station 2

Stifle ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot.

A one-way repeated measures ANOVA was organised to portray if there were statistically significant variations in stifle ROM (station 2) with the use of four various warmup interventions.

Data are mean ± standard deviation. Stifle ROM decreased from 102.3250 ± 14.23° with trot, to 98.6317 ± 5.34° with massage, decreasing further to 97.5567 ± 13.16° with no warmup, and finally decreased further to 93.8183 ± 7.56° with heat. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 3.994, p =0.562. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 19) between the warmup techniques, F (3, 15) = 0.610, P< 0.619. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

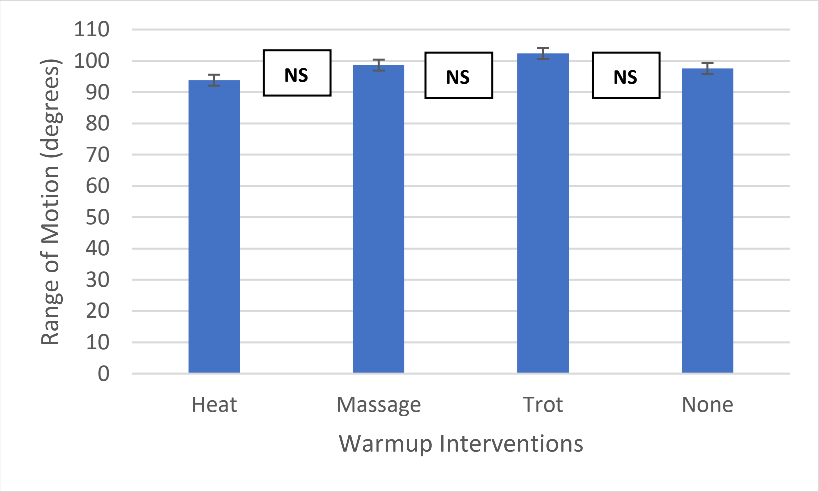


Figure 19: *The effect of heat, massage, trot, and no warmup on mean stifle ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.6.2 Stifle ROM- Station 3

Stifle ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test (p > .05). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was organised to portray if there were statistically significant variations in stifle ROM (station 3) with the use of four various warmup interventions.

Data are mean ± standard deviation. Stifle ROM decreased from 114.2033 ± 26.33° with trot, to 113.8800 ± 22.85° with massage, decreasing further to 113.3550 ± 36.18° with heat, and finally decreased further to 109.4117 ± 32.11° with no warmup. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 4.575, p =0.483. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 20) between the warmup techniques, F (3, 15) = 0.37, P< 0.990. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant p>0.05.

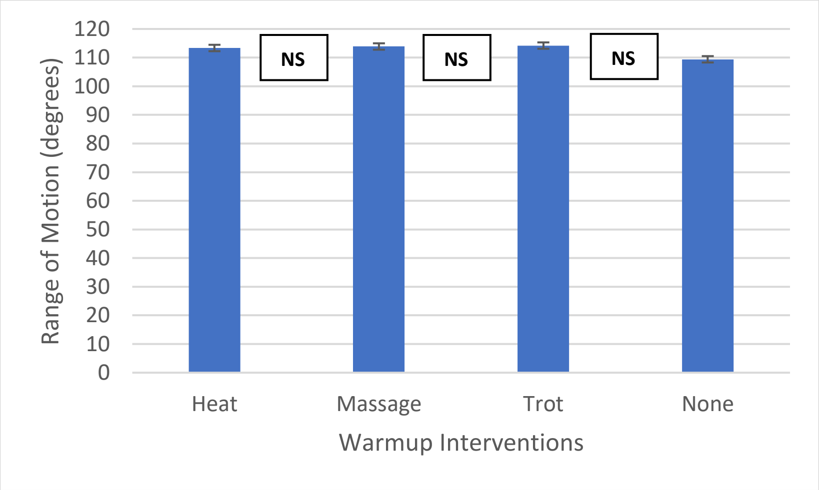


Figure 20: *The effect of heat, massage, trot, and no warmup on mean stifle ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.7 Tarsal ROM- Station 1

Tarsal ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test ($p > .05$). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was organised to portray if there were statistically significant variations in tarsal ROM (station 1) with the use of four various warmup interventions.

Data are mean ± standard deviation. Tarsal ROM decreased from 113.4183 ± 15.65° with massage, to 104.1383 ± 17.76° with trot, decreasing further to 94.2417 ± 23.89° with no warmup, and finally decreased further to 94.2117 ± 24.95° with heat. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 3.104, $p = 0.693$. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 21) between the warmup techniques, F (3, 15) = 1.047, $P < 0.401$. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant $p>0.05$.

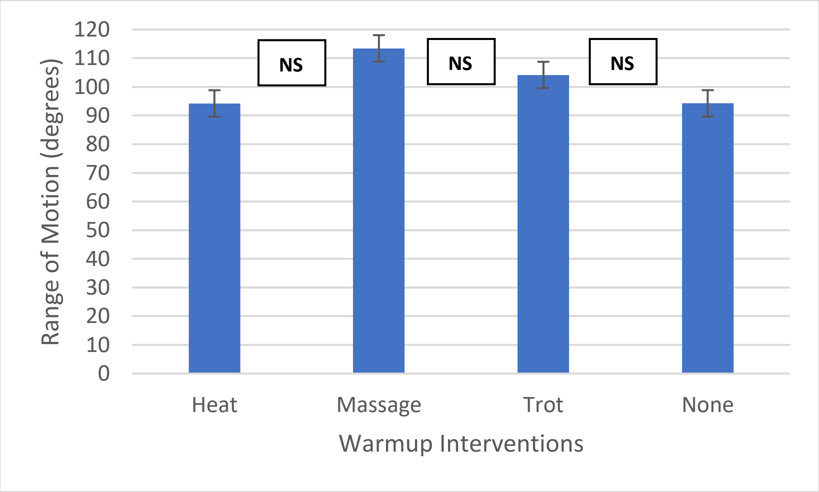


Figure 21: *The effect of heat, massage, trot, and no warmup on mean tarsal ROM station 1 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.7.1 Tarsal ROM- Station 2

Tarsal ROM was normally dispersed at each warmup, as adjourned by Shapiro-Wilk test ($p > .05$). There were no outliers in the data, as assessed by analysis of a boxplot. A one-way repeated measures ANOVA was organised to portray if there were statistically significant variations in tarsal ROM (station 2) with the use of four various warmup interventions.

Data are mean ± standard deviation. Tarsal ROM decreased from 129.76 ± 25.59° with no warmup, to 104.116.0117 ± 23.64° with trot, decreasing further to 111.6533 ± 11.21° with massage, and finally decreased further to 107.6250 ± 7.18° with heat. Mauchly's test of sphericity highlighted that the assumption of sphericity had not been violated, x^2 (5) = 16.130, p =0.008. On further analysis of the pairwise comparison of each warmup technique, it was noted that there were no significant differences (see Figure 22) between the warmup techniques, F (3, 15) = 1.403, P< 0.281. With four different interventions (i.e. warmup) there was a total of six possible combinations of differences between levels which all resulted in all pairwise comparisons being not significant $p>0.05$.

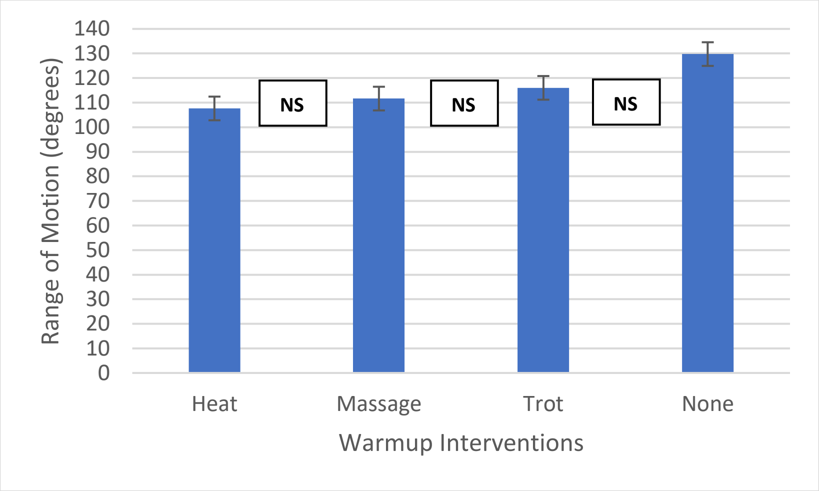


Figure 22: *The effect of heat, massage, trot, and no warmup on mean tarsal ROM station 2 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p>0.05) by one-way repeated measures ANOVA test.*

4.7.2 Tarsal ROM- Station 3

An initial normality test was carried out on middle (station 3) and it was noted that tarsal ROM was not normally dispersed with each warmup, portraying nonparametric data unlike station 1 & 2, as adjourned by Shapiro-Wilk test ($p < .05$). A Friedmans test was conducted to highlight if there were statistically significant variations in tarsal ROM (station 3) with the use of four various warmup interventions.

Pairwise comparisons were performed (SPSS Statistics, 2012) with a Bonferroni correction for multiple comparisons, with none outlined. Tarsal ROM was not statistically significantly different (see Figure 23) with the different warmups, X^2 (3) = 6.600, p = 0.086. Post hoc analysis portrayed no statistically significant variations in tarsal ROM between heat (mdn = 122.61°), massage (mdn = 149.38°), trot (mdn = 120.52°) and no warmup (mdn =95.84°).

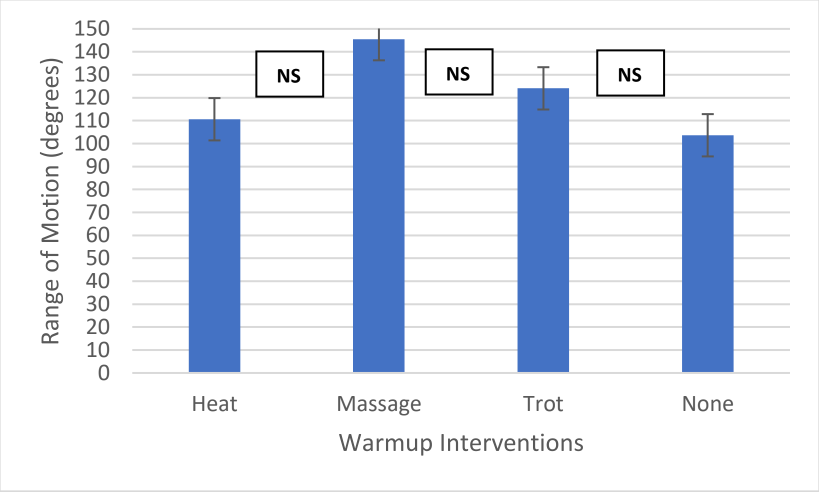


Figure 23: *The effect of heat, massage, trot, and no warmup on mean tarsal ROM station 3 (degrees). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p<0.05) by Friedman's test.*

4.7.3 Summary of ROM

All joints were initially subject to a normality test adjourned by Shapiro-Wilk test across three individual stations (start, middle and finish), resulting in parametric or non-parametric data. Moreover, this led to a one-way repeated measures ANOVA test if parametric (p>.05) or a Friedmans test if nonparametric (p<.05). The subsequent analysis of each joint (six joints, across three stations, over four days, with four interventions) showed no statistically significant difference of ROM amid warmups on any joint. Furthermore, each joint was also grouped together (across station 1, 2 & 3) in order to assess joints against each warmup intervention to view results as a whole, minimal differences were noted although no statistically significant differences were detected regarding any joint over the entire gallop.

5.1 Time

An initial normality test was carried out on time performance, and it was noted that time was not normally dispersed with each warmup, portraying nonparametric data, as adjourned by Shapiro-Wilk test ($p < .05$). Pairwise comparisons were performed (SPSS Statistics, 2012) with a Bonferroni correction for multiple comparisons, with none outlined. Time was not statistically significantly different (see Figure 24) with the different warmups, X^2 (3) = 1.576, p = 0.665. Post hoc analysis portrayed no statistically significant variations in time between heat (mdn = 10.6550), massage (mdn = 10.6450), trot (mdn = 10.5950) and no warmup (mdn = 10.6500) (p =1.000).

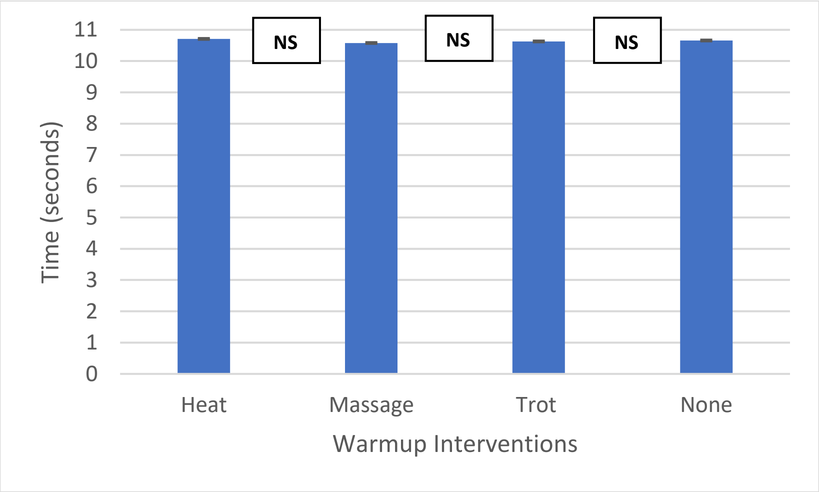


Figure 24: *The effect of heat, massage, trot, and no warmup on mean time (seconds). Error bars serve as standard deviation, (n=4). No statistical significance (NS) is recorded (p<0.05) by Friedman's test.*

5.1.1 Summary of Time

Similar to SL and ROM, an initial normality test was carried out on time performance, and it was noted that time was not normally dispersed with each warmup, portraying nonparametric data, as adjourned by Shapiro-Wilk test ($p < .05$). Subsequently, a Friedmans test was prescribed highlighting no statistically significant alterations amid time performance and warmups.

6. Discussion

The goal of this investigation was to measure the influence of various warmup techniques before exercise on the kinematics of racing greyhounds regarding SL, ROM, and time. This is one of the first experiments, to the author's expertise, to explore the effect of any warmup protocol over three different stages of gallop in any breed of dog. Significantly, heat, massage, and trot were found to independently have no statistical effect on SL, ROM, or time. Although, this determines no statistical significance regarding performance enhancement, the potential of these protocols to benefit racing greyhound injury prevention may be possible due to findings. An increase in mean joint ROM, an increase in SL or an improvement in time were not established to be significantly influenced by any warmup technique.

6.1 SL

From statistical analysis, SL was not found to substantially increase after heat, massage, or trot compared to no warmup, hence, the null hypothesis (H0.3) may be accepted. Moreover, all warmup techniques were not found to increase SL by which amounts to no increase in SL compared to no warmup. However, ($p = 1.00$) for all warmup interventions at each of the three stations (station 1, 2, 3) highlighting consistent significance of similarity between warmup techniques (see Section 4). Regarding SL as a whole, no statistical significance was observed, although minor alterations were seen.

6.1.1 Heat

Similar to trot and massage, heat also had minimal effect on increasing SL. Comparable to massage, the mechanisms of how heat operates is similar, increasing body and muscle temperature, improving flexibility/extensibility and encouraging circulation, potentially preventing musculoskeletal injuries (Heinrichs, 2004; Steiss & Levine 2005; Ishac & Eager, 2021; Kim *et al.,* 2019).

Heat is likely to cause to a change in blood flow to periarticular tissues and reducing stiffness of joints before exercise (McCutcheon *et al.,* 1999; Vainionpää *et al.,* 2012; Bleakley & Costello, 2013; Qadeer *et al.,* 2020). To the authors judgement, no investigations highlight any statistically significant increase in SL. Although, Knight *et al.,* (2001) found that after six weeks of using heat as a warmup protocol along with stretching ROM was enhanced, but no substantial difference in SL was observed in humans.

Also, prompt changes in muscle function after 10 minutes of heat may have occurred, yet this timeframe may not have been plentiful to evoke an increase in SL. Research into heat uses significantly more repetitions throughout a longer data collection period (Knight *et al.,* 2001; Frippiat & Votion, 2024), however, as the subjects in the present investigation had never had heat applied before exercise, a vigilant protocol was essential to create a calm atmosphere, and reduce the chances of any detrimental effects to the study.

In addition, heat was applied bilaterally to the *m. biceps femoris* of each subject before exercise (Section 3.4), suggested by (Usherwood & Wilson, 2005; Williams *et al.,* 2008) and similar to recommendations of (Millis, 2006), although, the time taken to implement heat for longer would have been unpractical within the timeframe of the investigation, or in the context of post event preparation due to greyhounds being kennelled before racing. Nonetheless, it must be noted that Vainionpää *et al.,* (2012) highlights the thin hair covering the *m. biceps femoris*, suggesting that some heat must have been lost, possibly altering the efficacy of heat as a warmup protocol. Thus, one must remember, canine dependant mechanisms such as panting/sweating evaporate heat loss (Morrison & Nakamura, 2011). Also, the decreased firing rate must be noted as nerves become hot resulting in serotonin binding the presynaptic neuron preventing the release of substance p (White, 1985; Darian-Smith & Johnson, 1997). Overall, this blocks pain to the thalamus, highlighting that although no statistical significance was found, long term benefits may occur such as decreased risk of injury by changing the intraarticular core temperature of tissue with the intention of repairing the prognostics of predisposed weaknesses such as muscle strain or stress fractures.

6.1.2 Massage

Similar to trot, the massage protocols implemented throughout this experiment potentially evoked a raise in blood flow, body and muscle temperature as well as extensibility/flexibility of muscle fibres (Tiidus, 1997; Zaworski *et al.,* 2014; Best & Crawford, 2017; Riley *et al.,* 2021; Baish *et al.,* 2022).

A comparable resemblance to trot was recognised in SL after implementing effleurage/tapotement massage techniques over three different stations (Weerapong *et al.,* 2005; Robinson *et al.,* 2015). To continue, these allegations indicate that the experiments by Wilson (2002) and Hill and Crook (2010) regarding horses, who noted an enhancement in SL after protocols in conjunction with, effleurage and other techniques does not compare to canines. Perhaps, a more intense combination of techniques is necessary such as a combination of techniques portrayed by (Robertson & Mead 2013; Corti, 2014).

Furthermore, it is challenging to decipher if either effleurage/tapotement may provoke effects if implemented for longer, or if combination of numerous techniques is required (Riley *et al.,* 2021) to reduce injury rates (Herman *et al.,* 2012). Although, tapotement is known to equip musculature for exercise by creating a stimulatory pump (Huneycutt & Davis, 2015; (Formenton *et al.,* 2017; Coates, 2018), its effectiveness has only been formerly entrenched regarding ROM by a defined amount of literature, particularly equines (Dimitrijevic *et al.,* 1980; Martin *et al.,* 1988; Badenhorst, 2016; Bergh *et al.,* 2022).

Substantially, while the complete massage warmup consisted of 10 minutes in length, according to Hill and Crook (2010), this is notably less than 30 minutes of massage on four individual muscles, proportionally. Nevertheless, it must be taken into consideration that to massage a complete equine muscle, in contrast to a greyhound, would take considerably longer due to difference in size and the efficacy of implementing longer periods of massage before racing is not feasible due to preperformance stress as greyhounds find it difficult to relax once at the racing stadiums. However, Mille *et al.,* (2022), found stress levels reduced with effleurage when treated at home by a veterinary physiotherapist. That said, environmental modifications must be made available to owners and trainers post racing to ensure sufficient warmup protocol.

6.1.3 Trot

Having seen no significant increase in SL after trot detected in the current investigation, it is not in synchroneity with Tiidus, (1997) or Morouco *et al.* (2017), who portrayed that 5 minutes of an 'easy run', 5 minutes of undefined drills, and two 'short distances of progressive running speed' increases SL in short distance sprinting in humans while encouraging healing. Similar to Morouco *et al*. (2017), nonetheless, the allegations in the present investigation are not statistically significant. Additionally, the present investigation used a similar duration of trot, providing a clinical basis for the allegations of Blythe *et al.,* (2007), although, controlled by stricter parameters.

The trot warmup protocol in the current investigation implements a clinical base for the assertations of McGonagle *et al.,* (2013) & Steiss *et al.* (2002), who advocate 5 to 10 minutes of trot prior to racing for greyhounds, to escalate muscle compliance. That said, even if the 5-minute range of their approach would be successful is yet to be known. As trot enhances blood flow, body and muscle flexibility/extensibility (Steiss, 2002; Faigenbaum & McFarland Jr, 2007; Repac *et al.,* 2020) muscle elasticity is reliant on these aspects (Avedesian *et al.,* 2018). Thus, SL in the present investigation is possibly the result of an increase in muscle extensibility, preventing injury and long term effects such as fatigue rather than performance related. Nevertheless, as post-activation potentiation arises after intense warmup (Smith *et al.,* 2014; Boullosa *et al.,* 2018; Blazevich & Babault, 2019), despite trot not being notably extreme, this is not expected to be the reason although, should not be entirely discounted.

6.1.4 Summary of SL

The increase in SL after the heat, massage, and trot is statistically insignificant, although warmup techniques have the possibility to increase performance and decrease injury risk (Gajer *et al.,* 1999; Mackala *et al.,* 2007).

Nonetheless, the probability of an enhancement in SL creating a positive influence in the prospect of performance injuries (Edwards *et al.,* 2009; Heidersheit *et al.,* 2011; Lenhart *et al.,* 2014; Willson *et al.,* 2014) is likely, specifically when it has been noted that the most common career ending injury in greyhounds is stress fractures to the tarsal joint due to cyclic concussive forces/repetitive strain (Walpole, 1944; Prole, 1974; Jones, 2009; Iddon *et al.,* 2014).

Investigations by Rowlands *et al.* (2001) indicated that eccentric muscular contraction accomplished at increased muscle lengths may create enhanced muscle fibre destruction, resulting in acute muscle injuries with greater SL, causing instability during gallop. On the other hand, Goslow Jr, *et al.,* (1981) highlights that storage of kinetic energy during gallop creates pendulum-like and spring-like structures for saving energy within each stride, as the subject decelerates to break the stride before accelerating upwards lifting its centre of mass, changing muscle length in the hindlimbs for a greater SL. The findings portrayed by Rowlands *et al.* (2001) is, nevertheless, conflicting with the work of Goslow Jr, *et al.,* (1981), who did not note any significant change in relation to SL, in fact saw a strong correlation with hindlimb muscle stability in gallop.

It is essential to consider that the previously mentioned investigations looked at SL in an unnatural approach with strict parameters, contrasted to that recognised during warmup protocols. Moreover, the likelihood of muscular injury may be reduced due to muscular preparation before exercise.

6.2 ROM

Under each warmup technique for all six joints examined, no substantial effect was noted regarding ROM, compared to no warmup; consequently, the null hypotheses (H0.1) could not be rejected. However, precise inclination of the allegations could be distinguished regarding insignificance. Imaginably, this came as a surprise when taking into consideration that heat (Bishop, 2003; Heinrichs, 2004; Vainionpää *et al.,* 2012; Kim *et al.,* 2019), massage (Drum *et al.,* 2015; Best & Crawford, 2017; Baish *et al.,* 2022) and trot (Faigenbaum & McFarland Jr, 2007; Robertson & Mead, 2013; Pääsuke *et al.,* 2014) have been proven to enhance ROM in recent studies. Despite being not statistically significant, minimal alterations were recognised.

6.2.1 Heat

The 10 minutes of heat divided into 5 minutes of heat to each hindlimb targeting the *m. biceps femoris* was shown to have no statistical increase on ROM. Heat warmup, nevertheless, was unsuccessful at increasing ROM of any observed joints over the whole course of gallop. Therefore, the absence of substantial findings is in disparity with numerous studies (Heinrichs, 2004; Williams *et al.,* 2008; Kim *et al.,* 2019).

Nonetheless, the above-mentioned investigations are mainly the effects of heat in relation to performance enhancement, thus heat may not be relevant as a warmup protocol in subjects who may potentially have repetitive strain (Heinrichs, 2004; Ishac & Eager, 2021). That said, diagnosis of injury may become a contraindication, for example if oedema is present (Blythe *et al.,* 2007). In addition, absence of significant differences noted is potentially positive due to the duration of heat applied alone rather than a combination of warmup techniques.

6.2.2 Massage

Although it has been shown that there is no significant statistical influence on ROM with massage as a warmup technique, it is worth noting that massage has the greatest impact on several different joints at different stations. The most noticeable impact massage had was on tarsal ROM station 3 (median +149.38°) which is 17.92% greater than the next highest impact, heat (median +122.61°), and 19.31% greater than that of the lowest impact warmup, trot (median +120.52°). Although massage was proven to have the greatest impact on tarsal ROM station 3 of all warmup techniques, as discussed, the overall influence of the warmup is proven to be non-significant with respect to overall ROM of all joints.

The scarcity of significance in the data is a contraindication with the findings of numerous investigations (Weerapong *et al.,* 2005; Zaworski *et al.,* 2014; Robinson *et al.,* 2015; Riley *et al.,* 2021). Nevertheless, the correlation of these studies with the present investigation is difficult when there are differing factors such as duration, different stages of gallop (taking off, full flight and slowing down), intensity, and massage techniques implemented. Furthermore, effleurage/tapotement have been noted to enhance ROM when combined with other massage techniques, but not in isolation.

The differences in the findings amid the present experiment and past allegations may possibly be as a result of discrepancies in duration of warmup (see Appendix 2). To continue, in the present investigation, 5 minutes of massage was achieved to each hindlimb of the subject, targeting the *m. biceps femoris.* Furthermore, this is significantly less time provided by the other investigations (Weerapong *et al.,* 2005; Zaworski *et al.,* 2014; Robinson *et al.,* 2015; Riley *et al.,* 2021).

Nevertheless, the massage techniques implemented were insufficient to significantly enhance ROM, although may have reduced injury risk. Dissimilar to McKechine *et al.* (2007), it was distinguished that 3 minutes of tapotement was adequate at enhancing plantar ROM in human studies and between 10-45 minutes was sufficient to increase shoulder ROM suggested by (Yeun, 2017). That said, the anatomical build of the canine compared to man has vast distinctions. Moreover, the allegations of the present investigation, nevertheless, are in unanimity with Barlow *et al.* (2004), who portrayed that 15 minutes of effleurage/petrissage to the hamstrings does not evoke changes in ROM. A similar study investigated by Rodenburg *et al.,* (1994), found correlating results with no change in ROM.

6.2.3 Trot

The 10 minutes of trot was found to have the greatest increase on mean carpal ROM (125.4400±23.73°) at station 2, which is not surprising considering subjects are in full flight of gallop. Whilst trot warmup increased mean carpal ROM at station 2 the greatest, the standard deviation of this evidence was substantial, hence, the data may possibly lack accuracy, possibly due to methodological limitations (see Section 3).

Furthermore, past investigations into trot as a warmup increasing ROM have used protocols that combined stretching (LaBan, 1962; Lehmann *et al.,* 1970; Stewart & Sleivert, 1998; Murphy *et al.,* 2010).

Granting stretching has been confirmed to reduce force production (Behm *et al.,* 2001), it has also been established to enhance ROM (Stewart and Sleivert, 1998; Behm *et al.,* 2016; Afonso *et al.,* 2021; Fukaya *et al.,* 2022). However, the noted enhancement in ROM in the mentioned investigations are potentially the result of the stretching techniques, rather than the influence of trot. Additionally, this present investigation highlights those further investigations on the effects of trot on ROM in isolation is necessary. Correspondingly, this experiment may highlight that trot as a warmup must coincide with another warmup technique to evoke a compelling response (see Appendix

2). Alternatively, a more intense period of trot, or longer protocol could be required to have more effect; however, if the protocol is too intense or too long, pre-event muscle fatigue may potentially occur (Steiss, 2002; Milgrom *et al.,* 2007).

6.2.4 Summary of ROM

Overall, each joint was analysed at each station in order to decipher if warmup had an influence at each of the stations i.e. starting, mid-flight and stopping. However, the different phases of gallop apply different forces on the limb's bony structures (Gillette & Angle, 2014) with surface impact evident throughout each phase of gallop (Mölsä *et al.,* 2010), indicating that warmup did not have a negative effect on each joint as a whole over the course of the gallop, or on any specific joint as a group. Moreover, this also depicts that long term benefits may occur with decreased risk of injury.

6.3 Time

The warmup protocols failed to provide a significant improvement in time performance compared to no warmup, therefore the null hypothesis H(0.2) could not be denied. Nevertheless, a clear trend was observed after the warmup, as all protocols had no influence; heat having the most effect on time with an increased median of (10.6550 seconds) compared to other warmup techniques. Data represents mean ± standard deviation. As stated previously, these findings are not statistically significant, the biological relevance may not be disclosed.

No changes were found throughout the current study which was surprising considering that (McCutcheon *et al.,* 1999; Avedesian *et al.,* 2018; Parisi, 2022) highlighted performance improvements with the use of warmup in human studies, such as coordination and high aerobic energy capacity. That said, recently, new statisticians are successfully allowing the possibility that data cannot be thoroughly concise and condensed through statistical analysis only (Lykken, 1968; EFSA, 2011; McShane *et al.,* 2019). These allegations are specifically applicable to the present investigation as the results detected with time pursue a clear trend, without any extreme values or compelling outliers that could possibly represent the results.

Nevertheless, warmup protocols may reduce injury risk in racing greyhounds; hence, this may be a biologically applicable conclusion (See appendix 2) for future recommendations. Thus, as heat creates vasodilation and reduces substance P being released, pain is blocked as pain endorphins become released such as oxytocin and serotonin, stimulating nerve fibres and potentially leading to better performance (Short, 1998; Iadarola *et al.,* 2021).

EFSA (2011) and Lovell (2013) both indicate that the effect size of biological purpose must be distinguished before initiating the investigation. That said, because of the scarcity of studies regarding the topic of kinematics and racing greyhound warmup protocols, a professional agreement of the effect size could not be decided. Fundamentally, the biological importance of warmup prior to exercise is positive but indeterminate.

7. Conclusion

To conclude, this study investigated the effects of individual warmup techniques prior to exercise in racing greyhounds. Granted there was a clear trend noted in the results, they were statistically insignificant regarding, SL, ROM and time, which rejects the hypothesis of this investigation (H1). That said, although there was no change in these parameters, they did not have a negative effect on performance and may have a massive influence on injury rates which perhaps a long-term study may highlight. Nevertheless, a combination of physiotherapeutic interventions may possibly result in compelling anatomical preparation which may result in a reduced injury risk for sporting athletes rather than enhancing performance during gallop.

8. Reference List

Afonso, J., Ramirez-Campillo, R., Moscão, J., Rocha, T., Zacca, R., Martins, A., Milheiro, A.A., Ferreira, J., Sarmento, H. and Clemente, F.M., 2021. Strength training is as effective as stretching for improving range of motion: A systematic review and meta-analysis.

Alanazi, H.M., 2016. Role of warming-up in promoting athletes health and skills. *International Journal of Scientific and Research Publications*, *6*(1), p.156.

Allen, K., DeCamp, C.E., Braden, T.D. and Balms, M., 1994. Kinematic gait analysis of the trot in healthy mixed breed dogs. *Veterinary and comparative orthopaedics and traumatology*, *7*(04), pp.148-153.

andLiam Delaney, T.F., 2006. State financial support for horse racing in Ireland. *Budget Perspectives 2007*, p.39.

Angle, C.T., Wakshlag, J.J., Gillette, R.L., Stokol, T., Geske, S., Adkins, T.O. and Gregor, C., 2009. Hematologic, serum biochemical, and cortisol changes associated with anticipation of exercise and short duration high-intensity exercise in sled dogs. *Veterinary Clinical Pathology*, *38*(3), pp.370-374.

Animals (Scientific Procedures) Act., 1986. [Online] Available at: https://www.legislation.gov.uk/ukpga/1986/14/contents [Accessed 25th April 2024].

Arifin, W. N., & Zahiruddin, W. M., 2017. Sample size calculation in animal studies using resource equation approach. The Malaysian Journal of Medical Sciences: MJMS, 24(5), pp. 101-110.

Au, J.S., 2022. *Biomolecular Response of Traumatized Skeletal Muscle to Electricallty Stimulated Eccentric Contraction Training* (Doctoral dissertation, Saint Louis University).

Avedesian, J.M., Judge, L.W., Wang, H. and Dickin, D.C., 2018. The biomechanical effect of warm-up stretching strategies on landing mechanics in female volleyball athletes. *Sports biomechanics*.

Badenhorst, J., 2016. *The Effects of Swedish Massage on Performance Horses in the Bloemfontein Area* (Doctoral dissertation, Bloemfontein: Central University of Technology, Free State).

Baish, J.W., Padera, T.P. and Munn, L.L., 2022. The effects of gravity and compression on interstitial fluid transport in the lower limb. *Scientific Reports*, *12*(1), p.4890.

Baker, N., 1996. Going to the dogs—Hostility to greyhound racing in Britain: Puritanism, socialism and pragmaticism. *Journal of Sport History*, *23*(2), pp.97-119.

Behm, D.G., Blazevich, A.J., Kay, A.D. and McHugh, M., 2016. Acute effects of muscle stretching on physical performance, range of motion, and injury incidence in healthy active individuals: a systematic review. *Applied physiology, nutrition, and metabolism*, *41*(1), pp.1-11.

Behm, D.G., Button, D.C. and Butt, J.C., 2001. Factors affecting force loss with prolonged stretching. *Canadian Journal of applied physiology*, *26*(3), pp.262-272.

Belshaw, Z., 2017. *Decision making and welfare assessment in canine osteoarthritis* (Doctoral dissertation, University of Nottingham).

Bergh, A., Asplund, K., Lund, I., Boström, A. and Hyytiäinen, H., 2022. A Systematic Review of Complementary and Alternative Veterinary Medicine in Sport and Companion Animals: Soft Tissue Mobilization. *Animals*, *12*(11), p.1440.

Bertram, J.E. and Gutmann, A., 2009. Motions of the running horse and cheetah revisited: fundamental mechanics of the transverse and rotary gallop. *Journal of the Royal Society Interface*, *6*(35), pp.549-559.

Bertram, J.E., Lee, D.V., Case, H.N. and Todhunter, R.J., 2000. Comparison of the trotting gaits of Labrador Retrievers and Greyhounds. *American Journal of Veterinary Research*, *61*(7), pp.832-838.

Best, T.M. and Crawford, S.K., 2017. Massage and postexercise recovery: the science is emerging. *British journal of sports medicine*, *51*(19), pp.1386-1387.

Birch, E. and Leśniak, K., 2013. Effect of fence height on joint angles of agility dogs. *The Veterinary Journal*, *198*, pp.e99-e102.

Bishop, D., 2003. Warm up II: performance changes following active warm up and how to structure the warmup. *Sports medicine*, *33*, pp.483-498.

Bishop, D., 2003. Warm up I: potential mechanisms and the effects of passive warm up on exercise performance. *Sports medicine*, *33*, pp.439-454.

Blazevich, A.J. and Babault, N., 2019. Post-activation potentiation versus post-activation performance enhancement in humans: historical perspective, underlying mechanisms, and current issues. *Frontiers in physiology*, *10*, p.479198.

Bleakley, C.M. and Costello, J.T., 2013. Do thermal agents affect range of movement and mechanical properties in soft tissues? A systematic review. *Archives of Physical Medicine and Rehabilitation*, *94*(1), pp.149-163.

Bliss, M., Terry, J. and de Godoy, R.F., 2022. Limbs kinematics of dogs exercising at different water levels on the underwater treadmill. *Veterinary Medicine and Science*, *8*(6), pp.2374-2381.

Blythe, L.L., Gannon, J.R., Craig, A.M. and Fegan, D.P., 2007. Care of the racing & retired greyhound. *Dostupné z: http://www. dogracing. cz/upload/greyhound_krev. pdf*.

Bockstahler, B.A., Henninger, W., Müller, M., Mayrhofer, E., Peham, C. and Podbregar, I., 2007. Influence of borderline hip dysplasia on joint kinematics of clinically sound Belgian Shepherd dogs. *American journal of veterinary research*, *68*(3), pp.271-276.

Boullosa, D., Del Rosso, S., Behm, D.G. and Foster, C., 2018. Post-activation potentiation (PAP) in endurance sports: A review. *European journal of sport science*, *18*(5), pp.595-610.

Burr, J.R., Reinhart, G.A., Swenson, R.A., Swaim, S.E., Vaughn, D.M. and Bradley, D.M., 1997. Serum biochemical values in sled dogs before and after competing in long-distance races. *Journal of the American Veterinary Medical Association*, *211*(2), pp.175-179.

Callaghan, M. J., 1993. The role of massage in the management of the athlete: a review. British Journal of Sports Medicine, 27(1), pp. 28-33.

Cameron, K.E., Vaughan, A., McAninch, M.J., Briden, K. and Dale, A., 2024. Cross-Sectional Survey of Public Perception of Commercial Greyhound Racing in New Zealand. *Animals*, *14*(2), p.207.

Carr, B.J. and Dycus, D.L., 2016. Canine gait analysis. *Recovery & Rehab*, *6*(2), pp.93-100.

Carr, B.J., Canapp Jr, S.O. and Zink, M.C., 2015. Quantitative comparison of the walk and trot of border collies and Labrador retrievers, breeds with different performance requirements. *PLoS One*, *10*(12), p.e0145396.

Carr, J. G., Millis, D. L., & Weng, H. Y., 2013. Exercises in canine physical rehabilitation: range of motion of the forelimb during stair and ramp ascent. Journal of Small Animal Practice, 54(8), pp. 409-413.

Carr, N., 2015. The greyhound: A story of fashion, finances, and animal rights. In *Domestic Animals and Leisure* (pp. 109-126). London: Palgrave Macmillan UK.

Cartlidge, H., 2014. How to perform effleurage and passive range of motion exercises. *The Veterinary Nurse*, *5*(7), pp.400-403.

Chatel, M.M., Tabor, G., Williams, J.R. and Williams, J.M., 2021. An evaluation of factors affecting show jumping warm-up on subsequent show jumping performance in 1.30 m class. *Comparative Exercise Physiology*, *17*(2), pp.109-121.

Cleophas, T.J., 1993. Carryover bias in clinical investigations. *The Journal of Clinical Pharmacology*, *33*(9), pp.799-804.

Coates, J.C., 2018. Manual therapy. *Canine sports medicine and rehabilitation*, pp.120-135.

Colborne, G.R., Innes, J.F., Comerford, E.J., Owen, M.R. and Fuller, C.J., 2005. Distribution of power across the hind limb joints in Labrador Retrievers and Greyhounds. *American journal of veterinary research*, *66*(9), pp.1563-1571.

Colborne, G.R., Walker, A.M., Tattersall, A.J. and Fuller, C.J., 2006. Effect of trotting velocity on work patterns of the hind limbs of Greyhounds. *American journal of veterinary research*, *67*(8), pp.1293-1298.

Corti, L., 2014. Massage therapy for dogs and cats. *Topics in companion animal medicine*, *29*(2), pp.54-57.

Cullen, K.L., Dickey, J.P., Bent, L.R., Thomason, J.J. and Moëns, N.M., 2013. Survey-based analysis of risk factors for injury among dogs participating in agility training and competition events. *Journal of the American Veterinary Medical Association*, *243*(7), pp.1019-1024.

Darian-Smith, I. and Johnson, K.O., 1977. Thermal sensibility and thermoreceptors. *Journal of Investigative Dermatology*, *69*(1), pp.146-153.

Davies, L., 2013. Canine rehabilitation. *Pain Management in Veterinary Practice*, pp.131-146.

De Bruyn-Prevost, P. and Lefebvre, F., 1980. The effects of various warming up intensities and durations during a short maximal anaerobic exercise. *European journal of applied physiology and occupational physiology*, *43*, pp.101-107.

DeCamp, C.E., 1997. Kinetic and kinematic gait analysis and the assessment of lameness in the dog. *Veterinary Clinics: Small Animal Practice*, *27*(4), pp.825-840.

DeCamp, C.E., Soutas-Little, R.W., Hauptman, J., Olivier, B., Braden, T. and Walton, A., 1993. Kinematic gait analysis of the trot in healthy greyhounds. *American journal of veterinary research*, *54*(4), pp.627-634.

Derrick, T. R., Hamill, J., & Caldwell, G. E., 1998. Energy absorption of impacts during running at various stride lengths. Medicine & Science in Sports & Exercise, 30(1), pp. 128-135.

Dimitrijevic, M. R., Gregoric, M. R., Sherwood, A. M., & Spencer, W. A., 1980. Reflex responses of paraspinal muscles to tapping. Journal of Neurology, Neurosurgery & Psychiatry, 43(12), pp. 1112-1118.

Disman, D., Ali, M. and Barliana, M.S., 2017. The use of quantitative research method and statistical data analysis in dissertation: an evaluation study. *International Journal of Education*, *10*(1), pp.46-52.

Drum, M.G., Bockstahler, B., Levine, D. and Marcellin-Little, D.J., 2015. Feline rehabilitation. *Veterinary Clinics: Small Animal Practice*, *45*(1), pp.185-201.

Drum, M.G., Marcellin-Little, D.J. and Davis, M.S., 2015. Principles and applications of therapeutic exercises for small animals. *Veterinary Clinics: Small Animal Practice*, *45*(1), pp.73-90.

Drust, B., Atkinson, G., Gregson, W., French, D. and Binningsley, D., 2003. The effects of massage on intramuscular temperature in the vastus lateralis in humans. *International journal of sports medicine*, *24*(06), pp.395-399.

Dybczyńska, M., Goleman, M., Garbiec, A. and Karpiński, M., 2022. Selected techniques for physiotherapy in dogs. *Animals*, *12*(14), p.1760.

Eager, H.H.D. and Walker, P., The effects of surface compliance on greyhound galloping dynamics.

Edwards, W. B., Taylow, D., Rudolphi, T. J., Gillette, J. C., & Derrick, R., 2009. Effects of stride length and running mileage on a probabilistic stress fracture model. Medicine & Science in Sports & Exercise, 41(12), pp. 2177-2184.

Eriksen, M.B. and Frandsen, T.F., 2018. The impact of patient, intervention, comparison, outcome (PICO) as a search strategy tool on literature search quality: a systematic review. *Journal of the Medical Library Association: JMLA*, *106*(4), p.420.

European Food Safety Authority Scientific Committee (EFSA), 2011. Statistical significance and biological relevance. EFSA Journal, 9(9), pp. 2372-2388.

Evans, C.J. and Crawford, B., 2000. Data collection methods in prospective economic evaluations: how accurate are the results?. *Value in Health*, *3*(4), pp.277-286.

Faigenbaum, A. and McFarland Jr, J.E., 2007. Guidelines for implementing a dynamic warm-up for physical education. *Journal of Physical Education, Recreation & Dance*, *78*(3), pp.25-28.

Farr, B.D., Ramos, M.T. and Otto, C.M., 2020. The penn vet working dog center fit to work program: a formalized method for assessing and developing foundational canine physical fitness. *Frontiers in Veterinary Science*, *7*, p.470.

Fenger, C. and Harrison, A.P., 2017. The application of acoustic myography in canine muscle function and performance testing. *Symbiosis Journal of Veterinary Science*, *3*, pp.1-6.

Formenton, M.R., Pereira, M.A.A. and Fantoni, D.T., 2017. Small animal massage therapy: a brief review and relevant observations. *Topics in companion animal medicine*, *32*(4), pp.139-145.

Foster, S., 2013. *Canine Cross Training: Building Balance, Strength, and Endurance in Your Dog*. Dogwise Publishing.

Fradkin, A.J., Gabbe, B.J. and Cameron, P.A., 2006. Does warming up prevent injury in sport? The evidence from randomised controlled trials? *Journal of Science and Medicine in Sport*, *9*(3), pp.214-220.

Fradkin, A.J., Zazryn, T.R. and Smoliga, J.M., 2010. Effects of warming-up on physical performance: a systematic review with meta-analysis. *The Journal of Strength & Conditioning Research*, *24*(1), pp.140-148.

France, D., Whalley, W.B. and Mauchline, A.L., 2013. Using mobile devices to enhance undergraduate field research. *Council on Undergraduate Research Quarterly*, *34*(2), pp.38-43.

Frippiat, T. and Votion, D.M., 2024. Warm-Up Strategies and Effects on Performance in Racing Horses and Sport Horses Competing in Olympic Disciplines. *Animals*, *14*(6), p.945.

Fuglsang-Damgaard, L.H., Harrison, A.P. and Vitger, A.D., 2021. Altered muscle activation in agility dogs performing warm-up exercises: an acoustic myography study. *Comparative Exercise Physiology*, *17*(3), pp.251-262.

Fukaya, T., Sato, S., Yahata, K., Yoshida, R., Takeuchi, K. and Nakamura, M., 2022. Effects of stretching intensity on range of motion and muscle stiffness: A narrative review. *Journal of Bodywork and Movement Therapies*, *32*, pp.68-76.

Gajer, B., Thepaut-Mathieu, C., & Lehenaff, D., 1999. Evolution of stride and amplitude during course ofthe 100 m event in athletics. Journal of Human Kinetics, 14(1), pp. 43-50.

George, R.P., Semendric, I., Bowley-Schubert, E.R., Chivonivoni, C.T., Warrender, A.P. and Whittaker, A.L., 2021. Reporting in rodent models of ‘chemobrain’: a systematic review assessing compliance with the ARRIVE guidelines. *Supportive Care in Cancer*, *29*(11), pp.7073-7084.

Ghadiyaram, D., Pan, J., Bovik, A.C., Moorthy, A.K., Panda, P. and Yang, K.C., 2017. In-capture mobile video distortions: A study of subjective behavior and objective algorithms. *IEEE Transactions on Circuits and Systems for Video Technology*, *28*(9), pp.2061-2077.

Gillette, Robert L., and T. Craig Angle. "Canine locomotion analysis." *Canine rehabilitation and physical therapy* (2014): 201-210.

Gillette, R.L. and Angle, T.C., 2008. Recent developments in canine locomotor analysis: a review. *The Veterinary Journal*, *178*(2), pp.165-176.

Gillette, R.L., Angle, T.C., Sanders, J.S. and DeGraves, F.J., 2011. An evaluation of the physiological effects of anticipation, activity arousal and recovery in sprinting Greyhounds. *Applied Animal Behaviour Science*, *130*(3-4), pp.101-106.

Gil, M.H., Neiva, H.P., Alves, A.R., Sousa, A.C., Ferraz, R., Marques, M.C. and Marinho, D.A., 2021. The effect of warm-up running technique on sprint performance. *The Journal of Strength & Conditioning Research*, *35*(12), pp.3341-3347.

Gil, M.H., Neiva, H.P., Sousa, A.C., Marques, M.C. and Marinho, D.A., 2019. Current approaches on warming up for sports performance: A critical review. *Strength & Conditioning Journal*, *41*(4), pp.70-79.

Giuffrida, M.A., 2014. Type II error and statistical power in reports of small animal clinical trials. *Journal of the American Veterinary Medical Association*, *244*(9), pp.1075-1080.

Gleim, G.W. and McHugh, M.P., 1997. Flexibility and its effects on sports injury and performance. *Sports medicine*, *24*, pp.289-299.

Goldner, B., Fuchs, A., Nolte, I. and Schilling, N., 2015. Kinematic adaptations to tripedal locomotion in dogs. *The Veterinary Journal*, *204*(2), pp.192-200.

Goodship, A.E. and Smith, R.K., 2008. Skeletal physiology: responses to exercise and training. *Hinchcliff KW, Geor RJ, Kaneps AJ. Equine Exercise Physiology–The Science of Exercise in the Athletic Horse*, *1*, pp.81-105.

Goslow Jr, G.E., Seeherman, H.J., Taylor, C.R., McCutchln, M.N. and Heglund, N.C., 1981. Electrical activity and relative length changes of dog limb muscles as a function of speed and gait. *Journal of Experimental Biology*, *94*(1), pp.15-42.

Granatosky, M.C., 2022. Greyhound racing. In *Encyclopedia of animal cognition and behavior* (pp. 3016-3019). Cham: Springer International Publishing.

Gray, S. and Nimmo, M., 2001. Effects of active, passive or no warm-up on metabolism and performance during high-intensity exercise. *Journal of Sports Sciences*, *19*(9), pp.693-700.

Grooms, D. R., Palmer, T., Onate, J. A., Myer, G. D., & Grindstaff, T., 2013. Soccer-specific warm-up and lower extremity injury rates in collegiate male soccer players. Journal of Athletic Training, 48(6), pp. 782-789.

Guilliard, M.J., 2000. Fractures of the central tarsal bone in eight racing greyhounds. *Veterinary Record*, *147*(18), pp.512-515.

Gustås, P., Pettersson, K., Honkavaara, S., Lagerstedt, A.S. and Byström, A., 2016. Kinematic and spatiotemporal assessment of habituation to treadmill walking in Labrador retrievers. *Acta Veterinaria Scandinavica*, *58*(1), pp.1-8.

Hagler, K.L., 2017. Fitness programs: rehab isn't just surgical recovery.

Hall, M., Bryant, A. L., Wrigley, T. V., Pratt, C., Crossley, K. M., Whitehead, T. S., Morris, H.G., Clark, R.A., Perraton, L. G., 2016. Does meniscal pathology alter gait knee biomechanics and - 75 - strength post-ACL reconstruction? Knee Surgery, Sports Traumatology, Arthroscopy, 24(5), pp. 1501-1509.

Harker, C., 2022. *Foundations for Performance Training: Skills for the Actor-Dancer*. Routledge.

Hayati, H., Eager, D. and Oberst, S., 2021, June. Recurrence Plot Qualification Analysis of the Greyhound Rotary Gallop Gait. In *Advances in Nonlinear Dynamics: Proceedings of the Second International Nonlinear Dynamics Conference (NODYCON 2021), Volume 2* (pp. 331-341). Cham: Springer International Publishing.

Hayati, H., Eager, D. and Oberst, S., 2021. Recurrence plot quantification analysis of greyhound galloping gait.

Hayati, H., Eager, D. and Walker, P., 2019. The effects of surface compliance on greyhound galloping dynamics. *Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics*, *233*(4), pp.1033-1043.

Hayati, H., Walker, P., Mahdavi, F., Stephenson, R., Brown, T. and Eager, D., 2018, November. A comparative study of rapid quadrupedal sprinting and turning dynamics on different terrains and conditions: Racing greyhounds galloping dynamics. In *ASME International Mechanical Engineering Congress and Exposition* (Vol. 52033, p. V04AT06A047). American Society of Mechanical Engineers.

Heiderscheit, B. C., Chumanov, E. S., Michalski, M. P., Wille, C. M., & Ryan, M. B., 2011. Effects of step rate manipulation on joint mechanics during running. Medicine and Science in Sports and Exercise, 43(2), pp. 296-300.

Heinrichs, K., 2004. Superficial thermal modalities. *Canine rehabilitation and physical therapy*, pp.279-282.

Hobbs, S. J., Levine, D., Richards, J., Clayton, H., Tate, J., & Walker, R., 2010. Motion analysis and its use in equine practice and research. Wiener Tierärztliche Monatsschrift, 9(3), pp. 55-64.

Hooijmans, C.R., Rovers, M.M., De Vries, R.B., Leenaars, M., Ritskes-Hoitinga, M. and Langendam, M.W., 2014. SYRCLE's risk of bias tool for animal studies. *BMC medical research methodology*, *14*, pp.1-9.

Hottinger, H.A., DeCamp, C.E., Olivier, N.B., Hauptman, J.G. and Soutas-Little, R.W., 1996. Noninvasive kinematic analysis of the walk in healthy large-breed dogs. *American journal of veterinary research*, *57*(3), pp.381-388.

https://www.oed.com/search/dictionary/?scope=Entries&q=speed.

Huneycutt, H.W. and Davis, M.S., 2015. Effect of pre-exercise massage on exercise-induced muscle injury in sled dogs. *Comparative Exercise Physiology*, *11*(4), pp.245-248.

Hurrion, P., 2009. A biomechanical investigation into weight distribution and kinematic parameters during the putting stroke. International Journal of Sports Science & Coaching, 4(1), pp. 89-105.

Iadarola, M.J., Brown, D.C., Nahama, A., Sapio, M.R. and Mannes, A.J., 2021. Pain treatment in the companion canine model to validate rodent results and incentivize the transition to human clinical trials. *Frontiers in Pharmacology*, *12*, p.705743.

Iddon, J., Lockyer, R.H. and Frean, S.P., 2014. The effect of season and track condition on injury rate in racing greyhounds. *journal of small animal practice*, *55*(8), pp.399-404.

Inkilä, L., Hyytiäinen, H.K., Hielm-Björkman, A., Junnila, J., Bergh, A. and Boström, A., 2022. Part II of finnish agility dog survey: agility-related injuries and risk factors for injury in competition-level agility dogs. *Animals*, *12*(3), p.227.

Inkilä, L., Hyytiäinen, H.K., Hielm-Björkman, A., Junnila, J., Bergh, A. and Boström, A., 2022. Part I of finnish agility dog survey: training and management of competition-level agility dogs. *Animals*, *12*(2), p.212.

Ishac, K. and Eager, D., 2021, January. Injuries in greyhound racing: Number of starters. In *26th Congress of the European Society of Biomechanics*.

Jeffreys, I., 2021. The warm-up. In *Advanced Personal Training* (pp. 129-142). Routledge.

Johnson, K.A., Muir, P., Nicoll, R.G. and Roush, J.K., 2000. Asymmetric adaptive modeling of central tarsal bones in racing greyhounds. *Bone*, *27*(2), pp.257-263.

Jones, J.M., 2009. Repair of hock fractures in racing greyhounds. *The Veterinary Record*, *165*(16), p.477.

Kilkenny, C., Browne, W.J., Cuthill, I.C., Emerson, M. and Altman, D.G., 2010. Improving bioscience research reporting: the ARRIVE guidelines for reporting animal research. *Journal of Pharmacology and Pharmacotherapeutics*, *1*(2), pp.94-99.

Kim, J., Williams, F.J., Dreger, D.L., Plassais, J., Davis, B.W., Parker, H.G., Ostrander, E.A. (2018) Genetic selection of athletic success in sport-hunting dogs. Proceedings of the National Academy of Sciences. 115(30), E7212–E7221.

Kim, K., Kuang, S., Song, Q., Gavin, T.P. and Roseguini, B.T., 2019. Impact of heat therapy on recovery after eccentric exercise in humans. *Journal of applied physiology*, *126*(4), pp.965-976.

Kloda, L.A., Boruff, J.T. and Cavalcante, A.S., 2020. A comparison of patient, intervention, comparison, outcome (PICO) to a new, alternative clinical question framework for search skills, search results, and self-efficacy: a randomized controlled trial. *Journal of the Medical Library Association: JMLA*, *108*(2), p.185.

Knight, C.A., Rutledge, C.R., Cox, M.E., Acosta, M. and Hall, S.J., 2001. Effect of superficial heat, deep heat, and active exercise warm-up on the extensibility of the plantar flexors. *Physical Therapy*, *81*(6), pp.1206-1214.

Kulund, D.N. and Töttössy, M., 1983. Warm-up, strength, and power. *Orthopedic Clinics of North America*, *14*(2), pp.427-448.

LaBan, M. M., 1962. Collagen tissue: Implications of its response to stress in vitro. Archives of Physical Medicine and Rehabilitation, 43, pp. 461-466.

Lehmann, J. F., Masock, A. J., Warren, C. G., & Koblanski, J. N., 1970. Effect of therapeutic temperatures on tendon extensibility. Archives of Physical Medicine and Rehabilitation, 51, pp. 481-487

Lenhart, R.L., Thelen, D.G., Wille, C.M., Chumanov, E.S. and Heiderscheit, B.C., 2014. Increasing running step rate reduces patellofemoral joint forces. *Medicine and science in sports and exercise*, *46*(3), p.557.

Lin, Wei-Cheng, Lee, C.-L., Chang, N.-J. (2020) Acute Effects of Dynamic Stretching Followed by Vibration Foam Rolling on Sports Performance of Badminton Athletes. Journal of Sports Science & Medicine. 19(2), 420–428.

Lovell, D.P., 2013. Biological importance and statistical significance. *Journal of agricultural and food chemistry*, *61*(35), pp.8340-8348.

Loya, A.K., 2020. *Understanding stretch activation and shortening deactivation in drosophila melanogaster*. Rensselaer Polytechnic Institute.

Lund, R.J., Guthrie, A.J., Mostert, H.J., Travers, C.W., Nurton, J.P. and Adamson, D.J., 1996. Effect of three different warm-up regimens on heat balance and oxygen consumption of thoroughbred horses. *Journal of applied physiology*, *80*(6), pp.2190-2197.

Lykken, D.T., 1968. Statistical significance in psychological research. *Psychological bulletin*, *70*(3p1), p.151.

Mackala, K., 2007. Optimisation of performance through kinematic analysis of the different phases of the 100 metres. New Studies in Athletics, 22(2), pp. 7-12.

Martin, N.A., Zoeller, R.F., Robertson, R.J. and Lephart, S.M., 1998. The comparative effects of sports massage, active recovery, and rest in promoting blood lactate clearance after supramaximal leg exercise. *Journal of athletic training*, *33*(1), p.30.

McCauley, L. and Van Dyke, J.B., 2018. Therapeutic exercise. *Canine sports medicine and rehabilitation*, pp.177-207.

McCutcheon, L.J., Geor, R.J. and Hinchcliff, K.W., 1999. Effects
horses. *Journal of Applied Physiology*, *87*(5), pp.1914-1922.

McGinley, J. L., Baker, R., Wolfe, R., & Morris, M. E., 2009. The reliability of three-dimensional kinematic gait measurements: a systematic review. Gait & Posture, 29(3), pp. 360-369.

McGonagle, L., Blythe, L. and Levine, D., 2013. Introduction to Physical Rehabilitation. *Canine Rehabilitation and Physical Therapy*, p.1.

McGowan, C.J., Pyne, D.B., Thompson, K.G. and Rattray, B., 2015. Warm-up strategies for sport and exercise: mechanisms and applications. *Sports medicine*, *45*, pp.1523-1546.

McKechnie, G. J., Young, W. B., & Behm, D. G., 2007. Acute effects of two massage techniques on ankle joint flexibility and power of the plantar flexors. Journal of Sports Science & Medicine, 6(4), pp. 498-501.

McShane, B.B., Gal, D., Gelman, A., Robert, C. and Tackett, J.L., 2019. Abandon statistical significance. *The American Statistician*, *73*(sup1), pp.235-245.

Milgrom, C., Radeva-Petrova, D.R., Finestone, A., Nyska, M., Mendelson, S., Benjuya, N., Simkin, A. and Burr, D., 2007. The effect of muscle fatigue on in vivo tibial strains. *Journal of biomechanics*, *40*(4), pp.845-850.

Mille, M.A., McClement, J. and Lauer, S., 2022. Physiotherapeutic strategies and their current evidence for canine osteoarthritis. *Veterinary sciences*, *10*(1), p.2.

Millis, D.L., 2006. Physical therapy for pain relief in canine osteoarthritis.

Mills, E.J., Chan, A.W., Wu, P., Vail, A., Guyatt, G.H. and Altman, D.G., 2009. Design, analysis, and presentation of crossover trials. *Trials*, *10*, pp.1-6.

Mölsä, S.H., Hielm-Björkman, A.K. and Laitinen-Vapaavuori, O.M., 2010. Force platform analysis in clinically healthy Rottweilers: comparison with Labrador Retrievers. *Veterinary Surgery*, *39*(6), pp.701-707.

Mori, H., Ohsawa, H., Tanaka, T. H., Taniwaki, E., Leisman, G., & Nishijo, K., 2004. Effect of massage on blood flow and muscle fatigue following isometric lumbar exercise. Medical Science Monitor, 10(5), pp. 173-178.

Morris, D., 2014. *Training and racing the greyhound*. Crowood.

Morrison, S.F. and Nakamura, K., 2011. Central neural pathways for thermoregulation. *Frontiers in bioscience: a journal and virtual library*, *16*, p.74.

Morouço, P. G., Helena Gil, M., Neiva, H. P., Marques, M. C., Sousa, A., & Marinho, D. A., 2017. The Effect of Warm-up on Sprinting Kinematics. ISBS Proceedings Archive, 35(1), pp. 283-286.

Mucha, M. and Bockstahler, B., PHYSIOTHERAPY AS A POSSIBILITY TO INCREASE QUALITY OF LIFE IN OLD DOGS. *Chair Scientific committee*, p.51.

Munk, N., Symons, B., Shang, Y., Cheng, R., & Yu, G., 2012. Noninvasively measuring the hemodynamic effects of massage on skeletal muscle: a novel hybrid near-infrared diffuse optical instrument. Journal of Bodywork and Movement Therapies, 16(1), pp. 22-28.

Murphy, J. R., Di Santo , M. C., Alkanani, T., & Behm, D. G., 2010. Aerobic activity before and following short-duration static stretching improves range of motion and performance vs. a traditional warm-up. Applied Physiology, Nutrition, and Metabolism, 35, pp. 679-690.

Nakano, J., Yamabayashi, C., Scott, A. and Reid, W.D., 2012. The effect of heat applied with stretch to increase range of motion: a systematic review. *Physical Therapy in Sport*, *13*(3), pp.180-188.

Nelson, A.G., Kokkonen, J., Eldredge, C., Cornwell, A. and Glickman-Weiss, E., 2001. Chronic stretching and running economy. *Scandinavian journal of medicine & science in sports*, *11*(5), pp.260-265.

Neiva, H. P., Marques, M. C., Barbosa, T. M., Izquierdo, M., & Marinho, A., 2014. Warm-Up and Performance in Competitive Swimming. Sports Medicine, 44, pp. 319–330.

Okazaki, Y., Kodama, K., Sato, H., Kitakaze, M., Hirayama, A., Mishima, M., Hori, M. and Inoue, M., 1993. Attenuation of increased regional myocardial oxygen consumption during exercise as a major cause of warm-up phenomenon. *Journal of the American College of Cardiology*, *21*(7), pp.1597-1604.

O’Neill, D.G., Church, D.B., McGreevy, P.D., Thomson, P.C. and Brodbelt, D.C., 2014. Approaches to canine health surveillance. *Canine genetics and epidemiology*, *1*, pp.1-13.

OST, P.C., DEE, J.F., DEE, L.G. and HOHN, R.B., 1987. Fractures of the calcaneus in racing greyhounds. *Veterinary surgery*, *16*(1), pp.53-59.

Pääsuke, M., Ereline, J., Gapeyeva, H., Kums, T. and Requena, B., 2014. Post-activation potentiation of skeletal muscles and its effect on enhancement of human motor performance: a review. *Наука и спорт: современные тенденции*, *3*(2 (3)), pp.15-22.

Page, M.J., Altman, D.G. and Egger, M., 2022. Assessing the risk of bias in randomized trials. *Systematic Reviews in Health Research: Meta‐Analysis in Context*, pp.55-73.

Page, P., 2012. Current concepts in muscle stretching for exercise and rehabilitation. *International journal of sports physical therapy*, *7*(1), p.109.

Palmer, A.L., Bolwell, C.F., Stafford, K.J., Gal, A. and Rogers, C.W., 2020. Patterns of racing and career duration of racing greyhounds in New Zealand. *Animals*, *10*(5), p.796.

Palmer, A.L., Rogers, C.W., Stafford, K.J., Gal, A., Cochrane, D.J. and Bolwell, C.F., 2020. Cross-sectional survey of the training practices of racing greyhounds in New Zealand. *Animals*, *10*(11), p.2032.

Paris, H.L., Sinai, E.C., Leist, M.A., Crain, C.M., Keller, A.M., Malysa, W. and Renzullo, S.C., 2021. Warm up intensity influences running performance despite prolonged recovery. *International Journal of Sports Science & Coaching*, *16*(5), pp.1196-1203.

Parisi, B., 2022. *The Anatomy of Speed*. Human Kinetics.

Parr, M., Price, P.D. and Cleather, D.J., 2017. Effect of a gluteal activation warm-up on explosive exercise performance. *BMJ Open Sport—Exercise Medicine*, *3*(1).

Poole, D.C. and Erickson, H.H., 2015. 41 Exercise Physiology of Terrestrial Animals. *Dukes' Physiology of Domestic Animals*, *70*(90), p.443.

Poulter, D., 1991. Greyhound injuries. *Acupuncture in medicine*, *9*(1), pp.35-39.

Prole, J.H.B., 1976. A survey of racing injuries in the greyhound. *Journal of Small Animal Practice*, *17*(4), pp.207-218.

Qadeer, U., Aftab, A. and Zahra, I., 2020. Effectiveness of Heat Therapy on Musculoskeletal Pain Before and After Exercise Therapy in Females. *International Islamic Medical Journal*, *2*(1), pp.30-34.

Ray, M.A., 2001. How much on that doggie at the window? An analysis of the decline in greyhound racing handle. *Review of Regional Studies*, *31*(2), pp.165-176.

Repac, J., Alvarez, L.X., Lamb, K. and Gillette, R.L., 2020. Evaluation of thermographic imaging in canine hindlimb muscles after 6 min of walking—A pilot study. *Frontiers in Veterinary Science*, *7*, p.224.

Riley, L.M., Satchell, L., Stilwell, L.M. and Lenton, N.S., 2021. Effect of massage therapy on pain and quality of life in dogs: A cross-sectional study. *Veterinary Record*, *189*(11), pp.no-no.

Ringaby, E. and Forssén, P.E., 2012. Efficient video rectification and stabilisation for cellphones. *International journal of computer vision*, *96*, pp.335-352.

Ringaby, E. and Forssén, P.E., 2014, May. A virtual tripod for hand-held video stacking on smartphones. In *2014 IEEE International Conference on Computational Photography (ICCP)* (pp. 1-9). IEEE.

Robertson-Dixon, I., Murphy, M.J., Crewther, S.G. and Riddell, N., 2023. The Influence of Light Wavelength on Human HPA Axis Rhythms: A Systematic Review. *Life*, *13*(10), p.1968.

Robertson, J. and Mead, A., 2013. *Physical therapy and massage for the dog*. CRC Press.

Robertson, J., 2010. *The Complete Dog Massage Manual: Gentle Dog Care*. Veloce Publishing Ltd.

Robinson, N.G., Sheets, S. and CMT, C., 2015. *Canine Medical Massage: Techniques and Clinical Applications*. American Animal Hosp Assoc.

Rodenburg, J.B., Steenbeek, D., Schiereck, P. and Bär, P.R., 1994. Warm-up, stretching and massage diminish harmful effects of eccentric exercise. *International Journal of sports medicine*, *15*(07), pp.414-419.

Rowlands, A. V., Eston, R. G., & Tilzey, C., 2001. Effect of stride length manipulation on symptoms of exercise-induced muscle damage and the repeated bout effect. Journal of Sports Sciences, 19(5), pp. 333-340.

Santos, C.M.D.C., Pimenta, C.A.D.M. and Nobre, M.R.C., 2007. Estrategia PICO para la construcción de la pregunta de investigación y la búsqueda de evidencias. *Revista latino-americana de enfermagem*, *15*, pp.508-511.

Shellock, F.G., 1986. Research applications: physiological, psychological, and injury pervention aspects of warm-up. *Strength & Conditioning Journal*, *8*(5), pp.24-27.

Short, C.E., 1998. Fundamentals of pain perception in animals. *Applied Animal Behaviour Science*, *59*(1-3), pp.125-133.

Sicard, G.K., Short, K. and Manley, P.A., 1999. A survey of injuries at five greyhound racing tracks. *Journal of small animal practice*, *40*(9), pp.428-432.

Silva, G.C., Cardoso, M.T., Gaiad, T.P., Brolio, M.P., Oliveira, V.C., Assis Neto, A., Martins, D.S. and Ambrósio, C.E., 2014. Kinematic gait analyses in healthy Golden Retrievers. *Pesquisa Veterinária Brasileira*, *34*, pp.1265-1270.

Silva, L.M., Neiva, H.P., Marques, M.C., Izquierdo, M. and Marinho, D.A., 2018. Effects of warm-up, post-warm-up, and re-warm-up strategies on explosive efforts in team sports: A systematic review. *Sports Medicine*, *48*, pp.2285-2299.

Singh, G., 2018. Biomechanical analysis of angle of knee joint at the time of short spiking skill in volleyball. International Journal of Physiology, Nutrition and Physical Education, 3(2), pp. 154- 158.

Smith, C. E., Hannon, J. C., McGladrey, B., Shultz, B., Eisenman, P., & Lyons, B., 2014. The effects of a postactivation potentiation warm-up on subsequent sprint performance. Human Movement, 15(1), pp. 36-44.

Spitz, M.G., Kenefick, R.W. and Mitchell, J.B., 2014. The effects of elapsed time after warm-up on subsequent exercise performance in a cold environment. *The Journal of Strength & Conditioning Research*, *28*(5), pp.1351-1357.

Staaden, R., 1984. *The exercise physiology of the racing greyhound* (Doctoral dissertation, Murdoch University).

Starling, M., Wilson, B. and McGreevy, P., 2020. Effects of lure type on chase-related behaviour in racing greyhounds. *Animals*, *10*(12), p.2262.

Steele, J.R., Milburn, P.D. and Roger, G.J., 1999. Warm-up effect on active and passive arthrometric assessment of knee laxity. *Archives of physical medicine and rehabilitation*, *80*(7), pp.829-836.

Steiss, J.E., 2002. Muscle disorders and rehabilitation in canine athletes. *Veterinary Clinics: Small Animal Practice*, *32*(1), pp.267-285.

Steiss, J.E. and Levine, D., 2005. Physical agent modalities. *Veterinary Clinics: Small Animal Practice*, *35*(6), pp.1317-1333.

Stewart, I.B., Sleivert, G.G. (1998) The effect of warm-up intensity on range of motion and anaerobic performance. The Journal of Orthopaedic and Sports Physical Therapy. 27(2), 154– 161.

Takeuchi, K., Takemura, M., Nakamura, M., Tsukuda, F. and Miyakawa, S., 2021. Effects of active and passive warm-ups on range of motion, strength, and muscle passive properties in ankle plantarflexor muscles. *The Journal of Strength & Conditioning Research*, *35*(1), pp.141-146.

Thacker, S.B., Gilchrist, J., Stroup, D.F. and Kimsey Jr, C.D., 2004. The impact of stretching on sports injury risk: a systematic review of the literature. *Medicine & Science in Sports & Exercise*, *36*(3), pp.371-378.

Tharwat, M., Al-Sobayil, F. and Buczinski, S., 2014. Influence of racing on the serum concentrations of acute-phase proteins and bone metabolism biomarkers in racing greyhounds. *The Veterinary Journal*, *202*(2), pp.372-377.

Thompson, L., 2003. *The dogs: a personal history of greyhound racing*. Summersdale Publishers LTD-ROW.

Tiidus, P.M., 1997. Manual massage and recovery of muscle function following exercise: a literature review. *Journal of Orthopaedic & Sports Physical Therapy*, *25*(2), pp.107-112.

Ting, K.H., Hill, C.L. and Whittle, S.L., 2015. Quality of reporting of interventional animal studies in rheumatology: a systematic review using the ARRIVE guidelines. *International Journal of Rheumatic Diseases*, *18*(5), pp.488-494.

Tomlinson, J. and Nelson, M., 2022. Conditioning dogs for an active lifestyle. *Veterinary Clinics: Small Animal Practice*, *52*(4), pp.1043-1058.

Tyler, C.M., Hodgson, D.R. and Rose, R.J., 1996. Effect of a warm-up on energy supply during high intensity exercise in horses. *Equine Veterinary Journal*, *28*(2), pp.117-120.

Usherwood, J.R. and Wilson, A.M., 2005. No force limit on greyhound sprint speed. *Nature*, *438*(7069), pp.753-754.

Vainionpää, M., Tienhaara, E.P., Raekallio, M., Junnila, J., Snellman, M. and Vainio, O., 2012. Thermographic imaging of the superficial temperature in racing greyhounds before and after the race. *The Scientific World Journal*, *2012*.

Vargas, N.T., Chapman, C.L., Johnson, B.D., Gathercole, R., Cramer, M.N. and Schlader, Z.J., 2020. Thermal behavior augments heat loss following low intensity exercise. *International Journal of Environmental Research and Public Health*, *17*(1), p.20.

Vargas, N.T., Chapman, C.L., Sackett, J.R., Abdul-Rashed, J., McBryde, M., Johnson, B.D., Gathercole, R. and Schlader, Z.J., 2018. Thermal behavior remains engaged following exercise despite autonomic thermoeffector withdrawal. *Physiology & behavior*, *188*, pp.94-102.

Walpole, R.O., 1944. Some preliminary observations and remarks on limb lameness in the racing track Greyhound. *The Veterinary Journal (1900)*, *100*(1), pp.11-16.

Walter, R.M. and Carrier, D.R., 2007. Ground forces applied by galloping dogs. *Journal of Experimental Biology*, *210*(2), pp.208-216.

Webster, E.L., Hudson, P.E., and Channon, S.B., 2014. Comparative functional anatomy of the epaxial musculature of dogs (C anis familiaris) bred for sprinting vs. fighting. *Journal of anatomy*, *225*(3), pp.317-327.

Weerapong, P., Hume, P. A., & Kolt, G. S., 2005. The mechanisms of massage and effects on performance, muscle recovery, and injury prevention. Sports Medicine, 35, pp. 235-256.

White, S.R., 1985. A comparison of the effects of serotonin, substance P and thyrotropin-releasing hormone on excitability of rat spinal motoneurons in vivo. *Brain research*, *335*(1), pp.63-70.

Williams, S.B., Wilson, A.M., Daynes, J., Peckham, K. and Payne, R.C., 2008. Functional anatomy and muscle moment arms of the thoracic limb of an elite sprinting athlete: the racing greyhound (Canis familiaris). *Journal of Anatomy*, *213*(4), pp.373-382.

Williams, S.B., Wilson, A.M., Rhodes, L., Andrews, J. and Payne, R.C., 2008. Functional anatomy and muscle moment arms of the pelvic limb of an elite sprinting athlete: the racing greyhound (Canis familiaris). *Journal of anatomy*, *213*(4), pp.361-372.

Willson, J. D., Sharpee, R., Meardon, S. A., & Kernozek, T. W., 2014. Effects of step length on patellofemoral joint stress in female runners with and without patellofemoral pain. Clinical Biomechanics, 29(3), pp. 243-247.

Wilson, J., 2002. The effects of sports massage on athletic performance and general function. Massage Therapy Journal, 41(2), pp. 90-100.

Yeun, Y.R., 2017. Effectiveness of massage therapy on the range of motion of the shoulder: a systematic review and meta-analysis. *Journal of physical therapy science*, *29*(2), pp.365-369.

Zaworski, K., Latosiewicz, R. and Majcher, P., 2014. Effectiveness of physiotherapeutic treatment of the upper limb lymphedema after a mastectomy procedure. *Medical Rehabilitation*, *18*, pp.4-10.

Zink, C. and Carr, B.J., 2018. What is a canine athlete? *Canine sports medicine and rehabilitation*, pp.1-22.

Zink, C., 2014. Sports retraining: an essential component of rehabilitation for the canine athlete.

9. Appendices

Appendix 1: ***Table 1:*** *Commonly massage techniques used on canines – edited from* Corti, (2014).

Technique	**Application**	**Effects**
Stroking	Hands are run smoothly over the targeted area, light pressure, gliding movement. Creates sensory awareness (Robertson & Mead, 2013).	• Encourages relaxation. • Reduces stress. • Improves blood flow and circulation. • Enhances flexibility/extensibility of muscle fibres.
Effleurage	Stroking from distal to proximal with medium pressure, increasing pressure as time goes on working deeper into the tissue (Robertson & Mead, 2013).	• Decreases pain. • Reduces oedema and swelling. • Reduces muscle tone. • Stimulates the nervous and parasympathetic system and encourages a relaxation response.

Compression E.g., kneading & wringing	Compressing muscles in a rhythmic manner. Alternating hands in opposite directions, one hand up one hand down with medium pressure (Robertson & Mead, 2013).	• Helps removal of waste products such as chemical irritants. • Reduces inflammation. • Increases strength and mobility of muscle fibres. • Helps to realign collagen cross fibres by breaking up adhesions.
Friction e.g., cross fibre friction	Small rotary movements with fingers, increasing pressure on the targeted area (Robertson & Mead, 2013).	• Reduces pain. • Breaks up trigger points. • Stimulates circulation (very localised). • Encourages blood flow.

Tapotement e.g., cupping, hacking, slapping	Cupped or straight hands with firmly held wrist. Brisk and rapid strikes between hands creating a stimulatory pump effect (Robertson & Mead, 2013).	• Enhances muscle tone. • Encourages circulation. • Stimulates muscle and tendon reflexes by a direct mechanical force.

Appendix 2: Recommendations and practical application for further study

Limitations (Section 3.5) have been highlighted, while yet desirable deviations in sensor placement between subjects have been noted due to variation in size and slight confirmation differences of the breed. Nonetheless, slight changeability in placement has not been noted to influence recordings, although the activity of the neighbouring musculature may have influenced the data collected. Nevertheless, more research surrounding warmup outcomes are required to implant how sensor placement influences overall findings. Furthermore, a previous investigation by Fenger & Harrison (2017) reported that the subject's hair was shaved prior to AMG recordings resulting in improved contact with the skin. Added supplementary investigations on AMG parameters are necessary to certify whether this factor effects results.

Moreover, although the sample size was plentiful for the animal within-subjects study with regards to testing the effects of three warmup techniques, as each subject was their own control, the same sample was divided into 4 groups for the 6 subject related factors to be statistically analysed. For future studies if warmup techniques are combined a larger sample size would be recommended as warmup interventions correlated may result in a high deviation and low power, possibly condensing the accuracy of results (Hooijmans *et al.,* 2014; Giuffrida, 2014).

Thus, for future studies, a range of different age groups would be advised to decipher if warmup had an influence on age variation.

To finish, as the subjects were handled by the same individual throughout the warmup protocol, it cannot be discharged that variation between handlers may have influenced findings by differences in execution of the different warmup techniques. Thus, the handler may have added to the movement of each subject throughout trot utilised for data collection, with considerable discrepancy during the trotting gait ensuing more trot strides due to the size and pace of each dog, adding to the carryover effect (Cleophas, 1993).

Investigations into understanding the effects of individual warmup techniques prior to exercise in racing greyhounds would be profitable for explaining and illustrating how damage may be reduced and stopped by correctly preparing the musculoskeletal system. Additionally, this is critical for the advancement and expansion of various sports such as agility, flyball and herding to enhance and encourage safety and longevity of their careers. Thus, it may support musculoskeletal health as they age and will permit these athletes to relish a practical retirement which is essential for their welfare and the continuation of greyhound racing. To continue, studies portrayed by Bell & Ferguson, (2009) and Gray *et al.,* (2011) both utilised passive heating to raise muscle temperature as a warmup prior to exercise. This varies to the current investigation where active and passive warmup parameters were chosen. However, while there has been no change in these parameters, this potentially indicates positivity surrounding performance benefits, as the warmup protocols did not highlight a negative effect on performance and may have a massive impact on injury rates which a long-term investigation may highlight.

Appendix 3. Limitations of the systematic review process

Nonetheless, this systematic review was organised according to the authoritative PRISMA guidelines, (Figure 25) and steps were put in place to assure bias introduction was reduced as much as possible. To start, only one individual oversaw the screening process, which may have increased error risk throughout the selection of publications in order to include/exclude as part of the review. That said, two or three assessors may have decreased this risk of bias, perhaps making the study more objective. Additionally, this involuntarily enhanced the prospects of disregarding admissible deposition. Nevertheless, databases were comprehensible to permit high quality and applicable results. Furthermore, not all research is indexed, a limitation that is completely out of the author's control. Regardless of search terms being attentively anticipated to enhance chances of discovering all compatible papers, with various terms and synonyms often noted in published research, warmup envelops numerous variations of protocols that some applicable terms could have been neglected, further weakening the search strategy. However, the patient, intervention, comparison, outcome (PICO) strategy was followed to ensure accurate research was being obtained from relevant search strategies (Eriksen & Frandsen, 2018; Kloda *et al.,* 2020). A flawless intact research question is critical for the recognition of applicable and significant evidence (Santos *et al.,* 2007). Besides, updated ARRIVE guidelines were followed during the review process, with tools used to channel the quality assessment ARRIVE and bias assessment SYRCLE for more objective and methodological results (Kilkenny *et al.,* 2010; Hooijmans *et al.,* 2014; Ting *et al.,* 2015; George *et al.,* 2021). Nevertheless, both tools are semi-qualitative, therefore it is impossible to exclusively avoid subjective bias. Thus, that is a reason why this review would have benefitted from another assessor.

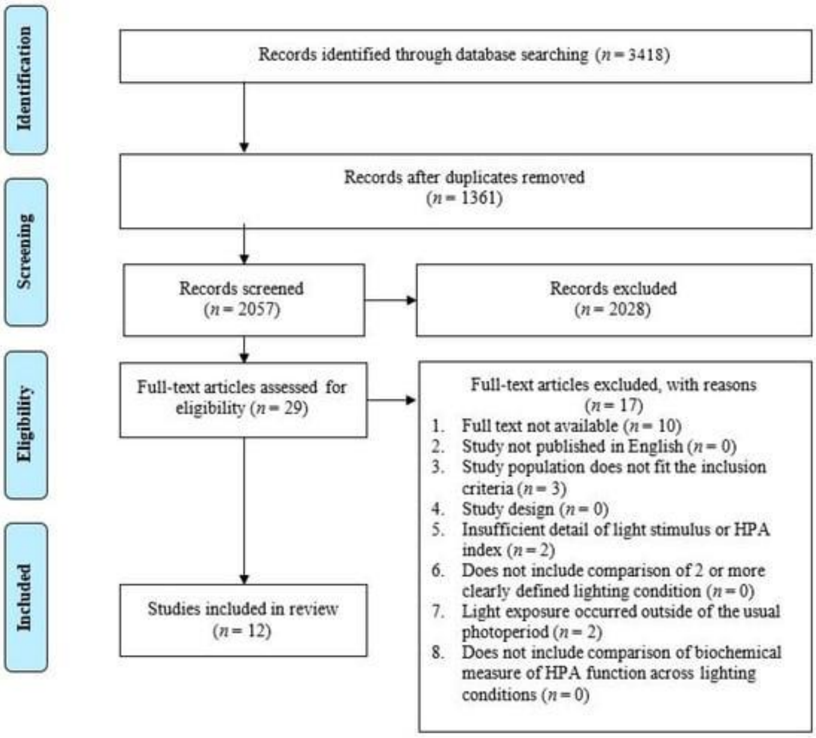


***Figure 25:** An example of a PRISMA flow diagram by Robertson-Dixon et al., 2023, similar to what was followed in the current study.*

Appendix 4. Limitations of the study

Regarding the misconception and negativity surrounding greyhound racing, all the subjects used in the study were fit, healthy and young athletes. This investigation was not without limitations, although attempts were made minimise these factors similar to Bliss *et al.,* (2022). Despite these subjects having completed a basic training and schooling as part of their qualification in order to be eligible to race, racing greyhounds tend to undergo more extensive training regime enabling them to cope with increased physical demand while attaining maximum performance (Poole & Erickson, 2015). Gillette *et al.,* (2011) found that greyhound heart rates were consistent throughout anticipation and during exercise.

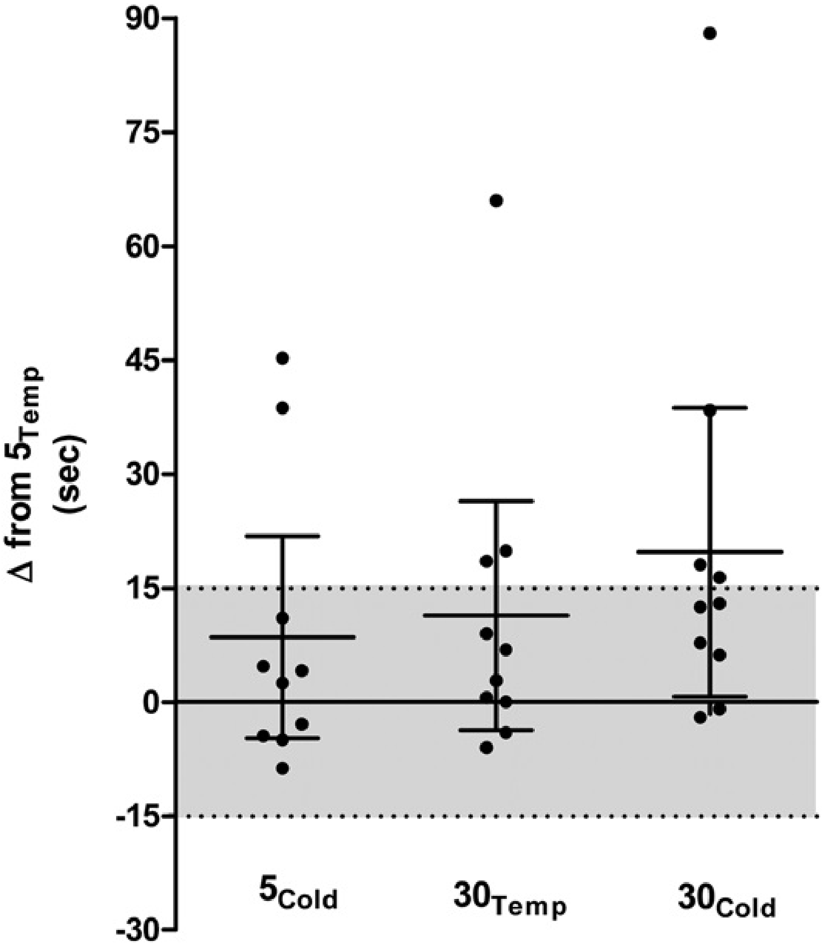
All of the greyhounds were on track with their usual routine when they arrived for data collection, this perhaps highlights that they were experiencing an anticipatory rise in heart rate which may have affected their performance by creating an increase in glycogen phosphorylase activity within musculature and altering concentrations of sodium, albumin and calcium in the blood (Burr *et al.,* 1997; Angle *et al.,* 2009; Gillette *et al.,* 2011). This could have possibly influenced the efficacy of results if this physiological alteration was developing in the subjects exercising on the days of data collection from the anticipation of working before arriving to the gallop.

However, a further constraint of this investigation was that there was no range in age of the dogs, suggesting there may have been differences in SL, ROM, and time regarding age. However, this is yet to be investigated. Bell and Ferguson, (2009) highlighted a raise in muscle temperature creates a decline in muscular capability and power output in comparison to an increase in younger participants.

Furthermore, as data tool place in January, weather conditions were cold. Hence, this may have affected warmup techniques, especially heat as subjects were beginning to cool down and lose heat rapidly in order to maintain normal body temperature noted in (Figure 26). Spitz *et al.,* (2014) found that when in a cold environment, the consolidation of increased heat loss after warmup exercise and longer rest cycle, ensue lower results in declining performance benefits of warmup (Shellock, 1986; Spitz *et al.,* 2014). Despite weather temperature being out of the authors control, the warmup possibly struggled to accurately represent the time it took for each technique to reach the correct temperature to have a significant effect. Therefore, a warmer climate would be recommended and implementing warmup inside would be a suggestion for future studies as weather and logistics can create a substantial delay between warmup and competition (Spitz *et al.,* 2014). That said, greyhound racing takes place all year round, suggesting a more detailed warmup may be necessary in wintry conditions. However, even though statistical analysis failed to accurately predict statistical significance warmup increased body temperature.

Additionally, as these subjects were young it may have been more accurate to use older subjects that have peaked in their racing careers to compile more accurate results in subjects who have reached maximum performance. Thus, as the subjects included in this investigation were expected to excel in their future careers and mature with age. Finally, perhaps longer warmup protocols are necessary as sated in (Knight *et al.,* 2001; Bishop, 2003; McGonagle *et al.,* 2013; Gil *et al.,* 2021; Jeffreys, 2021; Bergh *et al.,* 2022) to see statistically significant results. Although, not manageable within the time frame of this experiment or practical for a veterinary physiotherapist but it may be sustainable in the future if the correct warmup protocols become mandatory.

Figure 26: *Alteration of time trial performances (in seconds) in comparison to 5 (temperature). Solid line portrays mean value with 95% confidence interval bars. Gray area highlights estimated CV (±3.0%, which relates to 15 seconds) of rowing and running trials. Change values are calculated to ensure slower times occur as positive number (Spitz et al., 2014).*


Δ from 5_{Temp} (sec)
90
75
60
45
30
15
0
-15
-30
5_{Cold}
30_{Temp}
30_{Cold}