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A Preliminary Study on Amateur French Show Jumper and Dressage Riders: Can Riders Accurately Recall the Duration and Content of Their Warm-Up Routines?

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Abstract

Effective warm-up (WU) prior to exercise can increase performance and decrease injury risk. Little is known about how riders design and implement WU routines in training and competition. A two-phase study aimed to understand show-jumper and dressage rider decision-making when selecting WU routines during flatwork sessions at home. An initial survey identified the rider's perception of warm-up use and decision-making. Then, ten riders competing at intermediate levels in dressage (DR) (n = 7: 39 warm-ups) and show-jumping (SJ) (n = 3: 22 warm-ups) videoed their horses' WU; duration, gaits, transitions, and specific movements were recorded by a single observer. A post-warm-up form was completed by riders (DR: 4; SJ: 2; total WU = 44) to assess riders' memory and perception of their warm-up and gain information on external temperature, and horse/rider age. Rider WU profiles were formulated and differences were assessed through a series of Friedmans and Kruskal-Wallis analyses. Riders warmed up for a total of 24 mins ± 7.1 mins (DR: 22 mins 3 secs ± 6 mins; SJ 27 mins, 29 secs ± 8 mins). Riders spent the most time in walk (DR: 48.3%; SJ: 56.4%). Riders (88%), who recorded > 3 WUs, WU sessions significantly differed over time ($p < 0.03$). Out of the 44 WU analyzed, riders accurately recalled 13.6% of the routines. No significant differences in total WU duration or total time spent warming up in walk were found between temperatures < 5°C and > 30°C even though riders said they adapted their warm-up to the weather during stage 1 of this study. Warm-ups at home seem to be rider and horse-dependent but are not discipline or climate-specific when preparing for a flatwork session at home.

Keywords

Warm-up; showjumping; dressage; competition; equestrian sport

1. Introduction

In order to compete successfully in equestrian sports, horse riders must prepare their horses physically and mentally for competition; this requires regular training sessions where the cardiovascular and musculoskeletal systems of the horse are put under physiological stress [1]. An exercise session should be composed of a preparatory warm-up phase (WU), a planned training phase consisting of targeted exercises, and followed by a cool-down phase to facilitate recovery [2]. These individual sessions should be components of a broader conditioning program designed to achieve the core principles of training: preparing the horse physiologically and psychologically for the work expected, developing required motor skills and conditioning the neuromuscular system to perform these skills, and promoting health to prevent injury and extend career longevity [3]. Exercise sessions should align to the stage and level of training of both horse and rider and should be assessed to monitor how well they are contributing to the attainment of planned short- and long-term performance goals, as well as enabling evidence-informed decision-making in the rider to enable them to meet their duty of care to safeguard equine health and welfare [4].

In horses, an efficient warm-up regime has been shown to increase the use of the aerobic metabolic pathway resulting in lower heart rates and respiratory rates during subsequent competition, diminishing glucose expenditure as well as reducing lactic acid accumulation in the muscles [1,5,6]. This approach delays the onset of fatigue providing a potential performance advantage over other horses competing, which may have not been warmed up adequately [7–11]. The rider will also contribute to the horse's physiologic load and should therefore complete their own warm-up to ensure they are suitably prepared to ride and to reduce loading on the horse but also to optimize the performance of the horse and rider combination [4,12]. Riders' knowledge, skills, experience, and emotional state can therefore influence how well the warm-up prepares the horse to perform at their best [4,13]. However, studies [14–17] recording warm-up length in dressage and showjumping (SJ) at competitions have riders' warm-up routines, both within and across disciplines vary substantially in practice. For example, the warm-up duration of show jumpers varies from 12-27 minutes [14] to 4-63 minutes [16]. The content and duration of the warm-up in competition also appear to depend on the experience level of the rider as well as on the competition level [15,17,18].

1.1. Warm-Up in Training

The training environment provides athletes with an opportunity to develop their fitness, skills, and partnership, including determining what constitutes a successful competition warm-up, as well as requiring effective warm-up approaches for the different exercise sessions within it, to promote performance and prevent injury. Chatel and Williams [2] reported that riders tended to reflect on warm-up routine content and duration in the competition environment with less consideration given to warm-ups in training. It is known from previous research that most injuries occur during training [19,20], therefore, individualizing each warm-up routine depending on the need of each horse (his age, pathology, and training methods) could potentially decrease injuries and therefore decrease the number of days lost in training [21]. Knowing that, field studies observing SJ and DR riders warm-up at home have not been achieved yet as most studies concentrate on the competition aspect.

1.2. Perception vs Reality

In sports, the difference between a winning or losing performance can be attributed to differences in the physiological or psychological status of athletes [22,23] as well as the efficacy of training regimens [24]. Time distortion has been reported in athletes participating in other sports, with differences between memory recall and actual training content increasing with intense exercise [25] and increased emotion [26]. This phenomenon has also been documented within athlete support networks, for example, football coaches were only able to accurately recall between 30% and 59.2% of critical events during a match after games [27,28]. While human athletes often have coaches during their warm-up and training sessions to assist and guide them in their decision-making and stress-management related to their sports, in equestrian sports, for many riders the majority of training sessions will be undertaken independently, with the rider acting as a coach for the horse and self-coaching themselves [2]. The unique nature of equestrian sport therefore, where the rider is responsible for and has to manage their own and direct their horse's performance is likely to reduce further the efficacy of memory recall. At competitions, riders are more likely to have support in place, which could facilitate the opportunity to engage with technology and record performances, but often the focus will be on the competitive test neglecting the warm-up period and precluding evaluation of how this key phase of the competition period has affected subsequent performance. Time perception can be affected by different factors including temperature, personal enjoyment and investment in the task to be realized, emotional state, stress, prospective or retrospective timing, familiar vs unknown location as well as age of the participant studied [29].

1.3. Effective Decision-Making

Effective decision-making requires the individual to utilize their working, prospective, and long-term memory centers in the brain [30]. Prospective memory is the ability to formulate plans and intentions, to retain them, and to execute them upon the occurrence of the appropriate cues [31]. Prospective memory should therefore be used by a rider when implementing a warm-up prior to a training session. In this study, as riders were aware they were required to recall their warm-up an event-based test was used. Working memory is required for the perception of time and has been associated with sports skills [32,33]. It uses a combination of short-term and long-term memory for storage and movement based on memory [34]. Working memory engages different parts of the brain to be stored and used for decision-making and does not always seem to be age-dependent. However, appears to be influenced by experience, with recalling of event-based working memory reported to be superior in inexperienced individuals compared to novice athletes [30,32–34]. Memory and time perception can also be affected by the emotional state of the rider. During a competition, the athletes are subjected to higher stress levels which could affect their decision-making [13,35]. Other factors can influence decision-making, at shows most riders have a coach on the ground to help them manage their time and have a fixed competition time that they must respect, giving them guidance for the timeline of their warm-up [2].

At home, the rider should be undergoing less stress as there is no competition arousal, however, the fact that most riders train alone and have no set time to follow, makes it difficult to understand how they perceive time while riding [2].

Equestrian sports are facing increased scrutiny from the public as equestrianism's social license to operate is questioned [36]. Horse owners and riders have a duty of care to manage their horses effectively including suitable preparation for exercise [4,36]. An increased knowledge and understanding of what constitutes an ideal equine warm-up, and what factors influence this, is currently lacking across horse sports. This information is needed to underpin evidence-informed practice and effective rider decision-making [2,4]. An important stage in this process is to understand current practice; therefore, this study aimed to evaluate the WU practices utilized by experienced dressage DR and SJ riders prior to flat work sessions in their home environment, to determine if extrinsic factors such as temperature affected WU content and duration. As well as determining if riders could recall the details of their horse's WU accurately. According to the results of previous studies in a competition environment,

it was also hypothesized that at home, dressage riders would warm up for a longer period than show-jumpers.

2. Materials and Methods

A two-stage study was designed to evaluate French riders' perception of equine warm-up via 1) an online survey, and 2) to assess their warm-up routine and recollection of their warm-up using video recording as well as a specific questionnaire. Ethical approval for the study was granted by the Hartpury University Ethics Committee (Ethics 2019-51 and Ethics No: 2019-58) for both the horses and riders, data protection was ensured and approved within this process.

2.1. Online Survey

The first stage of the study utilized data collected via an online survey of French riders' perception of their warm-up protocols and daily decision-making within these (for further details please refer to [2]. Part of the results collected in this survey have been published previously, however, the data used in this article were not analyzed in [2]. The study was designed as an online questionnaire (Survey Monkey®) with a total of 39 questions for DR riders and 41 questions for SJ riders. The first seven questions were common to both SJ and DR riders and were multiple choice questions related to the respondents' age, and nationality as well as their equestrian life and experiences. The survey was then divided into discipline-specific questions on warm-up routines. The dressage survey consisted of three open questions, ten Likert questions, and 26 multiple-choice questions. The survey for SJ riders consisted of three open questions, ten Likert questions, and 28 multiple-choice questions; the two additional questions for SJ riders related to using jumping within warm-up regimes. For this study, answers to questions 4, 18, 20, 27, 36, 38, 48, 50, 60, and 69 were analyzed to provide insight into non-ridden warm-up routines, and how rider perception of the influence of environmental conditions influenced decision-making related to warm-up. Please refer to [2] for a detailed overview of the method.

2.2. Warm-Up Routine, Perception vs Reality

A combined observational and phenomenological research design was utilized to gather video data of rider warm-up sessions and compare individual recall of the structure of these to the videos using self-completed training diaries. In this study, an event-based test was used to assess prospective and working memory in the recall of the warm-up routine.

Show jumpers and dressage riders were recruited via convenience sampling through social media to take part in the study. To be eligible to participate, riders had to be over 18 years old and be currently based and competing in DR or SJ in France (from Elementary up to Prix Saint George in dressage and from 90 to 120cm for SJ). Participating riders declared their horses to be sound and able to participate in the study. Horses were checked at least annually by a veterinarian. During the study, if a horse became lame, the videos recorded before the lameness occurred were used and the horse was then removed from the study; this was the case for one horse. If the horse had a known pathology, riders were asked to write it down and also write if their warm-up routine was changed due to the horse's prior pathology.

Riders were asked to record a video of the entirety of warm-up routines completed while training at home using either a smartphone or other device compatible with a computer between May 2020 and December 2020. Each rider was asked to record up to ten videos on different days over 8 months. To be eligible for the study, the recording device had to be placed in the same spot for the same rider to facilitate recording different warm-up routines. The video had to be of good quality and the horse rider dyad was not allowed to leave the video frame for more than 3 seconds if the recording device could not cover the entire riding arena. The riders were asked to record their usual warm-up routine for the training sessions about to take place. Within 12 hours of each training session being recorded, riders then had to complete a training session record form to recall the content and duration of activities within the warm-up recorded **(Table 1)**. On the form riders/participants were also asked to write what type of work session they were preparing for.

2.3. Data Collection and Analysis

Each rider recorded their own warm-up routine and uploaded the video to YouTube™ on a private listing. Training forms were completed and sent via email with the link to the video to be analyzed by a consistent observer (MC). Videos were played and paused every time a change of rein or gait/movement occurred. This allowed for analysis of variables studies as recorded in **Table 1**. The data collected were then entered anonymously on a Microsoft Excel Version 2019 (IBM, New York, USA) spreadsheet to enable rider warm-up profiles to be formulated.

Data met non-parametric assumptions and are reported as median ± IQR unless otherwise stated. A series of Friedman's analyses identified if significant differences occurred in individual riders' warm-up routines recorded by video and their perception of the same warm-up recorded via memory recall. Where significant differences existed, post-hoc Wilcoxon analyses identified where differences occurred between individual training sessions. For each rider, further Wilcoxon analyses examined if video-recorded warm-up content differed in perception or recalled content across all warm-up sessions recorded. For each warm-up routine, Wilcoxon analyses also compared warm-up duration and components to air temperature. Kruskal-Wallis analyses identified if differences occurred in warm-up duration and content, between riders and across the disciplines represented. Where significant differences existed, post-hoc Mann Whitney U analyses identified where differences occurred. Significance was set at $p < 0.05$; all analyses were conducted using SPSS Version 26 (IBM, London, UK).

Table 1: Variables recorded in training session form.

Rider name	Assigned unique identifier code
Horse name	Assigned unique identifier code
Date	Date of the training session
Weather	Raining, foggy, sunny, humid, windy
Environmental temperature	Air temperature recorded in Celsius degrees
Total warm-up time	Total seconds warming up; measured from mounting to when rider self-selected their flatwork warm-up was complete
Time spent in each gait	Cumulative seconds spent in halt, rein-back, walk, trot, and canter during the rider-defined warm-up period
Time spent on each rein	Cumulative seconds spent in walk, trot, and canter during the rider-defined warm-up period for the left and right rein, respectively
Time spent in different head carriage	Cumulative seconds spent in walk, trot, and canter during the rider-defined warm-up period where the horse's head is either below his chest level or above it (as seen in **Figure 1**)
Time spent in lateral work	Cumulative seconds spent engaging in specific lateral work movements (e.g. shoulder-in, half-pass) during the rider-defined warm-up period

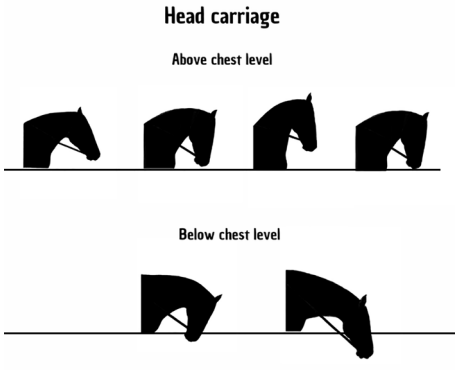

Figure 1: Head carriage classification.

3. Results

3.1. Stage 1: Survey

A total of 257 riders completed the survey and the majority (60%, n = 155) warmed up independently or with support from a coach or another rider (38,9%, n = 100). The survey found no significant differences between warm-up regimes between DR and SJ riders [2]. Respondents were asked to outline any non-ridden warm-up regimes followed, 70.1% (n = 125) stated they hand-walked their horses as a warm-up before riding, 61.8% (n = 54) manually massaged their horses and 16.5% (n = 24) used a massage pad on their horses before riding. Respondents were also asked what head carriage they used at the beginning of the warm-up during the walking phase, 93.8% (n = 160) responded they walked their horses either on a loose rein or in a low and round frame. The majority of DR (71%, n = 62) and SJ riders (70%, n = 64) included lateral work in the warm-up.

Respondents were also asked how their warm-up practice and decision-making varied with time of year and in response to environmental conditions; 60.1% (n = 107) agreed warm-up duration should vary depending on the time of the year. Respondents (24%, n = 22) self-reported that during winter, the warm-up should be longer as it takes longer to warm up horses' muscles. The original survey was used to inform stage 2 design (refer to [2] for additional survey results).

3.2. Stage 2: Warm-Up Routines, Perception vs. Reality

For the warm-up observation, ten female riders took part in the study (n = 7 DR; n = 3 show jumpers); however, only six of these (n = 4 dressage riders; n = 2 show jumpers) returned their training forms, aged 22 to 51yo age mean 33 ± 9.7 (mean: DR: 32yo; SJ: 35yo). Therefore, a total of 61 warm-up video routines were analyzed (n = 39 dressage; n = 22 show jumpers) and a total of 44 forms were completed (n = 21 dressage; n = 23 show jumpers). The total warm-up duration for each rider is described in **Table 2**. The age of the horses used in the study ranged from 8 to 19yo, mean of 12yo ± 3.1 (DR 12yo; SJ 11yo).

3.3. Video Analysis of Warm-Ups

Warm-up duration in the arena for all riders ranged from 8:04 minutes to 42:07 minutes. All riders warmed up in an outdoor arena, except for rider 2 who warmed up in an indoor arena. None of the riders hand-walked their horses as part of the warm-up regime; one rider (10%) used a massage pad on her horse prior to ridden warm-up. WU duration across all horse and rider combinations was 23 ± 8 mins (mean 24 ± 7 mins). Dressage riders warmed up for 22 ± 10 mins (mean 22 ± 6 mins), while showjumpers warmed up for 27 ± 10 mins (mean 27.5 ± 8 mins). Dressage riders spent ~2% longer on the left rein, while SJ riders spent ~2% longer on the right rein when warming up.

Riders spent the most time in walk (average: DR: 10 ± 4 mins; SJ: 15 ± 7 mins) and trot (DR: 7 ± 4; SJ: 8 ± 2 mins), and the least time in canter (DR: 4 ± 3 mins; SJ: 4 ± 2 mins). During the first walk phase (before trotting or cantering) 80% of the riders (n = 8) walked their horses with a low head carriage (head below chest level). The low head carriage in the first walk phase was used in 67% of the warm-up routines of dressage riders (n = 26) and in 95% of the show jumpers (n = 20).

All riders used halt (84 ± 7 secs) and rein-backs (32 ± 6 secs) when warming up. Dressage riders performed on average 26 transitions per warm-up routine, ~44% more than show jumpers who performed on average 18 transitions per warm-up routine. Lateral work was used by 100% of the DR and only by 30% of SJ riders during their WU. Overall, lateral work was used in 72% of dressage warm-up routines (28/39) and accumulated an average time of 1:30 min (±1), a median of 1 minute. Lateral work was used in 14% of SJ warm-up routines (3/22) and accumulated an average time of 12 seconds (±36), a median of 0.

When the warm-up routines of individual riders were compared across the period recorded, no significant differences were found for either the gaits used, warm-up duration, or the time spent on each rein during the warm-up. A similar pattern was observed when comparing intra- and inter-discipline warm-up routines across riders; with no significant differences found between riders' warm-up routines.

Table 2: Total warm-up (WU) duration range and mean (mins).

	Rider 1	Rider 2	Rider 3	Rider 4	Rider 5	Rider 6	Rider 7	Rider 8	Rider 9	Rider 10
WU length range (mins)	20–32	13–32	21–31	22–42	21–23	12–31	20	20–32	12–21	8–28
WU length (median)	23	24	26	31	22	18	20	24	20	22
WU length Mean (mins)	25	23	27	31	22	21	20	25	18	19

3.4. Rider Recall of Warm-Up Routines

Riders consistently demonstrated poor recall of the warm-up content, either over-estimating or under-estimating the total time spent warming up and the time spent in each gait **(Table 3)**. Out of the 44 warm-ups analyzed, riders recalled total WU time accurately in only 13.6% (n = 6) of the recorded routines. A total of 13 WU routines were under-estimated and 25 WU routines were overestimated. Time spent in walk, trot, and canter was correctly assessed in 11.4%, 13.6%, and 18.2% respectively.

Total warm-up routine time was under-estimated by up to 10 mins and over-estimated by up to 13 mins. Time spent in walk, trot, and canter were under-estimated by up to 13, 4, and 6 mins, respectively, and over-estimated at most by 12 mins for the walk and 10 mins for the trot and canter.

There was a trend for riders to over-estimate the time spent for the total warm-up, and time spent in walk, trot, or canter, rather than under-estimate the time spent warming up (**Table 4** and **Table 5**); however, the range of time over-estimation was smaller than under-estimation for all variables. The rider's age had no significant impact on warm-up recall.

Riders reported environmental temperatures ranging between 3°C and 39°C for the study period. The number of routines for each temperature variation is presented in **Table 6**. No significant differences in total warm-up duration or the total time spent warming up in walk were found between sessions in temperatures below 5°C and temperatures above 30°C.

Table 3: Duration of total warm-up, walk, trot, and canter in videos versus rider's perception; WU: warm-up.

Rider	WU	Total WU duration (mins)	Total WU duration (mins)	Diff in mins	Time in walk (mins)	Time in walk (mins)	Diff in mins	Time in trot (mins)	Time in trot (mins)	Diff in mins	Time in canter (mins)	Time in canter (mins)	Diff in mins
	Session	Actual	Perception		Actual	Perception		Actual	Perception		Actual	Perception	
1	1	21	20	-1	14	15	1	0	1	1	5	4	-1
	2	23	30	7	13	20	7	5	4	-1	12	6	-6
	3	29	30	1	13	20	7	4	4	0	5	6	1
	4	32	30	-2	10	20	10	4	2	-2	11	8	-3
	5	20	20	0	14	16	2	2	0	-2	2	4	2
2	1	21	20	-1	13	10	-3	7	10	3	0	0	0
	2	13	20	7	13	7	-6	5	10	5	1	3	2
	3	27	35	8	13	22	9	8	12	4	5	5	0
	4	32	27	-5	16	20	4	12	10	-2	2	2	0
	5	26	20	-6	26	26	0	8	10	2	2	3	1
	6	24	25	1	10	15	-5	8	10	2	2	5	3
	7	28	30	2	18	5	-13	7	10	3	0	5	5
	8	16	15	-1	6	19	-13	10	10	0	2	1	-1
3	1	22	30	8	9	6	-3	9	9	0	4	4	0
	2	31	30	-1	14	10	-4	8	8	0	8	8	0
	3	30	30	0	14	14	0	10	15	5	6	12	6
	4	28	30	2	15	8	-7	7	14	7	6	15	9
	5	23	30	7	20	14	-6	12	16	4	7	10	3
	6	23	30	7	11	20	9	8	16	8	4	12	8
	7	21	30	9	11	20	9	6	14	8	4	12	8
	8	26	30	4	17	20	4	7	14	7	2	12	10
	9	27	30	3	11	14	3	10	16	6	6	10	4

Rider	WU	Total WU duration (mins)	Total WU duration (mins)	Diff in mins	Time in walk (mins)	Time in walk (mins)	Diff in mins	Time in trot (mins)	Time in trot (mins)	Diff in mins	Time in canter (mins)	Time in canter (mins)	Diff in mins
	Session	Actual	Perception		Actual	Perception		Actual	Perception		Actual	Perception	
4	1	31	35	4	25	25	0	5	10	5	2	5	3
	2	39	45	6	28	29	1	8	12	4	3	5	2
	3	36	35	-1	25	22	-3	7	8	1	3	3	0
	4	22	25	3	14	18	4	5	8	3	2	2	0
	5	26	25	-1	14	12	-2	7	10	3	5	6	1
	6	33	30	-3	20	17	-3	7	6	-1	5	5	0
	7	42	45	3	25	29	4	10	10	1	4	6	2
	8	31	30	-1	20	17	-3	7	8	1	4	6	2
	9	20	30	10	11	16	5	6	8	2	3	6	3
5	1	21	33	12	11	10	-1	4	5	1	3	4	1
	2	22	35	13	8	20	12	9	5	-4	5	4	-1
	3	23	27	4	9	20	11	9	5	-4	5	4	-1
6	1	17	20	3	8	16	8	2	10	8	7	4	-3
	2	31	30	-1	13	12	-1	13	12	-1	5	6	2
	3	12	12	0	3	6	3	5	4	-1	3	2	-1
	4	19	19	0	9	9	0	5	5	0	3	5	2
	5	12	13	1	8	9	1	4	5	1	0	0	0
	6	27	27	0	8	10	2	13	13	0	4	6	2
	7	15	15	0	8	8	0	3	5	2	3	4	1
	8	25	26	1	14	9	-5	5	7	2	7	9	2
	9	29	19	-10	11	8	-3	10	7	-3	7	4	-3
	10	18	30	12	8	12	4	5	15	10	4	5	1

Table 4: Time overestimated by the riders for total warm-up duration, walk, trot, and canter; WU: warm-up.

Overestimation	Number of routines overestimated (out of 44)	% of routine overestimated	Median %
Total WU duration	25	56.8	14
Walk	24	54.5	30
Trot	28	63.6	32
Canter	26	59.1	28

Table 5: Time underestimated by the riders for total warm-up duration, walk, trot, and canter; WU: warm-up.

Underestimation	Number of routines underestimated (out of 44)	% of routine underestimated	Median (%)
Total WU duration	13	29.5	4
Walk	15	34.1	24
Trot	10	22.7	29
Canter	9	20.5	44

Table 6: Number of WU routines and temperatures.

Temperature in °C	Number of WU routines	Number of routine indoor	Number of routine outdoor
0–5	2	0	2
6–10	6	0	6
11–15	8	0	8
16–20	5	1	4
21–25	4	1	3
26–30	11	2	9
31–35	7	3	4
36–40	1	1	0

4. Discussion

4.1. Reality versus Perception – What Do Riders Recall of Their Warm-Up and How do they Assess Time?

Even though the number of riders was a limiting factor for phase two of this study, none of the riders could recall accurately their warm-up sessions in terms of duration or time spent in different gaits and activities each time. Interestingly, there was no clear trend for riders to under- or over-estimate the length of the warm-up completed but overestimation of the time seems. One rider could underestimate one training session

and overestimate the next one. There were however more WU routines overestimated than underestimated. While total warm-up duration does not seem to impact performance on the day in SJ, the warm-up intensity does impact performance [37,38]. If riders perform a more intense warm-up than they intend to, this could decrease their performance and increase injury risk by increasing repetitive stress on the horse's musculoskeletal structure [39]. Similarly, a shorter warm-up could lead to an increased injury risk as optimal core and muscle temperature might not be reached. Not knowing accurately how much time is spent in each gait could also be an issue for warming up specific muscles required for skilled movements such as jumping or lateral work. According to the survey, 71% of DR and 70% of SJ riders said they included lateral work in the warm-up, however, stage 2 of this study showed that 100% of the DR used lateral work and only 30% of SJ riders used lateral work during their WU. In humans, discipline-specific warm-up routines have been shown to be more efficient in reducing injury risk and increasing performance for athletes [40,41]. It is also important to note that human athletes can assess their pain level and adapt their warm-up and training accordingly, however, horses cannot verbally articulate how they are feeling and as a prey species, may pain guard making detection of pain and sub-clinical injuries more difficult to assess [42]. Riders have a duty of care to safeguard the welfare of horses in their care including ensuring they are adequately prepared for the demands humans place upon them [4]. Riders should therefore ensure they have sufficient knowledge and understanding of how to formulate warm-up routines that prepare their horses for the activities and demands of work expected of them but are also capable of recognizing behavioral and performance cues that could indicate distress, pain, or injury in their horse.

Inaccurate recall of prior activities is widely recorded in sports [25,43–45]. Many factors are associated with this including increased fatigue [43], higher exercise intensities [44,45], lower levels of training and experience [25], and heightened emotional states: stress, anxiety, or arousal [43]. From a rider's perspective, the potential impact of psychological state or fatigue on their own and their horses' performance should also be considered, especially in competitive environments to enable riders to plan ahead and perhaps adopt a more regimented warm-up. While this information was not recorded in the riders here, further research is warranted to determine if any underlying rider factors could be associated with the variability of under- and over-estimating both the duration and content of warm-ups observed here. The emotional state of the rider can also change within a riding session depending on horse behavior and the rider's emotional reaction to the environment [46] and fatigue may occur across a competition. Riders should be cognizant that based on these results, the likelihood of not accurately recalling warm-up is high, resulting in decision-making potentially being compromised or at best based on inaccurate appraisal. As such we would recommend the use of planned and documented exercise and training regimes aligned with core goals to optimize performance in the horse and rider [47].

4.2. Prospective and Working Memory

Time perception depends on prospective and working memory. In this study, participants were aged 22 to 51yo (mean 33yo). While aging can have an effect on long-term and working memory, no correlation was found in this study between the age of the participants and the accuracy of warm-up recollection [34]. Another parameter that can affect working memory and recall of activities is learning disorders, which were not assessed here [48].

Participants were asked to fill out the form recalling their warm-up within 12 hours post-warm-up; this timescale will rely on long-term memory recall [31]. Long-term memory can be disturbed by daily events as well as the emotional state and fatigue of the participant at the moment of memory recall [49]. Score recall in eventers was found to differ between riders depending on their final score [50]. This study did not concentrate on competition however it could be assumed that how the training session went could also affect the recall of the warm-up.

4.3. Warm-Up Duration

Warming-up is an essential component of the work routine of the equine athlete to increase performance and decrease injury risk [39,51]. Human studies have shown that core temperature starts to increase 3-5 mins after the onset of exercise, before reaching a plateau 15-20 mins later [40]. Increasing core temperature is an important factor of warm-up as it increases muscle blood flow and oxygen uptake, as well as optimizing metabolic reactions [40]. For the human athlete, a 1°C increase in muscle temperature has been reported to lead to an improved performance from 2 to 5% during short-duration exercise [52]. Our results found warm-up routine duration and content varied between riders and between warm-up routines for the same horse and rider combinations independently of the type of training session planned. This suggests the warm-up routines assessed in this study were rider and horse dependent, and were selected on a day-to-day basis, as the content of individual warm-up regimes was not consistent or linked to obvious extrinsic or intrinsic variables.

Anecdotally, equestrian lay literature suggests a low-intensity warm-up of between 10 and 20 minutes is warranted to prepare the horse for more intense exercise. The average warm-up duration in this study was 24 ± 7 mins, which equates to the warm-up duration (18-25 mins) advocated to increase core temperature in preparation for exercise in the human athlete. Few studies have evaluated the thermodynamics of equine warm-up. One of the first studies conducted on equine core temperature during exercise found that walking for 6 mins, followed by a 3-4 mins break, and then trotting for 11 mins had no significant changes on equine core temperature. When 14 minutes of cantering was added, the core temperature increased significantly [53]. More recently, Janczarek *et al.* [39] reported increasing external body temperature measured by thermography for very short-extended, and long-lasting warm-ups, although the duration of each of these was not stated. The duration of warm-up reported here is also slightly longer than previously reported in the assessment of WU at competitions [14–16,18]. This could be due to riders spending longer warming up at home than at shows, where increased flexibility in warm-up duration and content are more accessible. For the purpose of this study, riders were asked to only record their warm-up, they therefore had to differentiate between the warm-up phase and the actual training phase.

During competition differentiating both phases might be easier as the real exercise occurs in the show ring.

4.4. Warm-Up Content

In phase 2 of this study, none of the riders hand-walked their horses prior to their ridden warm-up which contradicts the survey results where 70.1% of the riders stated they hand-walked their horses before riding. Understanding, if hand walking is a useful stage of warm-up in order to prepare the horse's back without a rider, is needed.

DR warmed up on average 22 ± 6 mins while SJ warmed up on average 27.5 ± 8 mins. Out of the total time spent on warm-up, riders spent on average 10 ± 4 mins and 15 ± 7 mins in walking for DR and SJ, respectively. Therefore, approximately half of their warm-up is spent in a low energy-consuming gait, which does not raise core temperature significantly but will increase HR and respiratory frequency **[39,53]**. However, walking has its utility, during the walk the ground reaction force (GRF) of the forelimb fetlock joint increases to 20.6 N Kg^{-1}, which allows for the flexor tendons to warm up gradually **[54]**. In trot, the GRF is increased to 40.6 N Kg^{-1} and is further increased to 45.9 N Kg^{-1} in canter **[54]**. While cantering is the most efficient gait to increase core temperature and heart rate to maximal values, it also increases forces on the forelimb tendons and distal joints. The repetitive stress and high concussion forces can potentially cause damage to the distal limbs **[55–57]**.

A warm-up should also increase an athlete's heart rate to prepare the cardiovascular system for the demands of exercise. In human athletes, warm-up aims to increase the heart rate to 40–80% of HR max in preparation for the ongoing demands of exercise, increasing to up to 90% of HR max for explosive sports **[40]**. Barrey and Valette **[58]** reported a mean heart rate value of 166bpm (87.4% of HR_{max}) for show jumpers during a competition warm-up, despite all horses completing very different warm-up routines in terms of duration and number of jump attempts. Lower heart rates have been reported in dressage horses; Williams **[37]** reported average heart rates of 91bpm (63% and 62% of HR_{max} respectively for elementary and medium level) during warm-up for horses warming-up for elementary and medium level Dressage tests. Further work to consider the dynamic relationship between the duration, intensity, and type of activities performed within the warm-up is required to fully elucidate what constitutes an appropriate warm-up regime for different disciplines, levels of competition, and individual horses.

Another important factor to take into account is muscle warm-up. While both SJ and DR self-report that they know their horses are ready to work when they feel supple, each muscle will work differently depending on the gait and arena footing used **[21,59,60]**. Few studies compare muscular activation in all three gaits (walk, trot, and canter), but it is important to consider which muscles will be needed to facilitate the activities required by the horse during exercise to ensure these are prepared adequately in the warm-up. This approach is commonplace in human sports; for example, in basketball athletes, where the ankle joint is the main site of injuries, the use of a specific warm-up targeting ankle muscles three times a week, increases ankle range of motion and stability, decreasing injury **[61]**. In horses, muscle activity during work is poorly studied but muscle activation will vary in action across the gaits; gait velocity and in/decline will also modify muscle activation **[62–66]**. Understanding equine muscle activation with consideration of the environmental conditions and requirements of exercise is therefore important for riders to understand what muscles should be warmed up for different equestrian disciplines in order to promote optimal performance and decrease injury risk.

4.5. Show Jumping versus Dressage

Both SJ and DR riders utilized the walk with the horse's head and neck long and low, as the main warm-up gait at home. A similar approach was reported by Murray *et al.* **[15]** in the competition environment; however, Chatel *et al.* **[14]** found show jumpers self-reported they used the trot as their main warm-up gait. In the competition environment, it has been observed that show jumpers jump during their warm-up, and dressage riders practice dressage movements before their test **[15]**. However, this was not observed in this study as warm-up occurred at home. During training, show jumpers do not jump throughout every training session, therefore if they planned to have a flat work session or a dressage session to supple up their horses, jumping would not be necessary. The same can be observed for dressage riders at home, if the rider planned to have a stretching session, then practicing dressage movements during the warm-up would not be necessary. In the SJ horse, it has been observed that varying the type of work and surface could decrease injury risk, it is therefore important that both show jumpers and dressage riders vary their type of work and adapt their warm-up accordingly to the exercise planned for individual sessions **[19]**.

4.6. Environmental Conditions and Their Influence on Warm-Up

Within the initial stage of this study, 60.1% (n = 107) of respondents stated warm-up duration should vary depending on the time of the year; with 24% (n = 22) self-reporting that during winter, the warm-up should be longer as it takes longer to warm up horses' muscles. However, this proved to not be the case in practice for the riders recording warm-ups, with no significant differences in duration or gait used between warm-up routines reported at 3°C or 39°C. In human athletes it has been proposed that while warming up in a hot environment (30°C and above), muscle temperature should remain just above the resting temperature baseline as nerve transmission is impaired in higher temperatures and endurance capacity is also decreased **[67]**. Hot and/or humid conditions should be considered a core component of decision-making when determining warm-up routines and exercise levels for the equine athlete as muscle hyperthermia can lead to acidosis, decrease performance, and increase the risk of musculoskeletal pathologies, as well as contribute to potential heat thermodynamic compromise **[68]**. Therefore, in a hot environment, a shorter warm-up might be more beneficial for the cardiovascular health of the horse but also performance and welfare. Knowing that heat has an impact on the "cognitive load" of human athletes, it has been observed that increased core temperature has a negative effect on time perception **[67,69]**; further consideration if a similar impact occurs in riders is warranted.

5. Conclusion

This study has found that warm-up routines undertaken at home during training seem to be rider and horse-dependent

but are not discipline or climate-specific. On average, both dressage and show jumpers tend to warm up equally on both reins at home and use the walk as the main warm-up gait. Riders did not adapt their warm-up routines in response to external climate conditions. High levels of inaccurate recall of the duration and content of warm-up routines were also recorded, suggesting riders as athletes experience high levels of time distortion, which could impact decision-making, performance, and ultimately the welfare of the horse. Riders should take into consideration the individual horse, the demand of their discipline, and the external climate when planning and implementing their warm-up routines to safeguard equine performance and welfare. Equine warm-up remains an under-studied and poorly understood subject despite the warm-up underpinning performance and equine welfare by decreasing injury risks. Further research is warranted to evaluate how warm-up routines prepare the horse and rider as individual athletes, and as a combination, for the psychological and physiological demands of exercise and competition.

Authors' Contributions

Conceptualization: MC and JMW; methodology: MC and JMW.; data collection: MC; data analysis: JMW; writing—original draft preparation: MC ; writing—review and editing: MC and JMW. All authors have read and agreed to the published version of the manuscript.

Data Availability

Data are unavailable due to privacy restrictions.

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The authors declare no conflicts of interest.

Ethical Approval

This project received ethical approval from the Hartpury University Ethics Committee (Ethics 2019-51 and Ethics No: 2019-58))

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