Self-selected versus standardised warm-ups; physiological response on 500-m sprint kayak performance

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Abstract: This study investigated the effectiveness of a self-selected (SS) warm-up on 500 m sprint kayak performance (K500) compared to continuous (CON) and intermittent high intensity (INT) type warm-ups. Twelve nationally ranked sprint kayakers (age 17.7 ± 2.3 years, mass 69.2 ± 10.8 kg) performed a CON (15 minutes at the power at 2 m·mol⁻¹), INT (10 minutes at 2 m·mol⁻¹, followed by 5 x 10 s sprints at 200% power at VO2max with 50 s recovery at 55% power at VO2max) and SS (athlete’s normal competition warm-up) warm-up in a randomised order. After a five-minute passive recovery, K500 performance was determined on a kayak ergometer. Heart rate, blood lactate (BLa) were recorded before and immediately after each warm-up and K500 performance. Ratings of perceived exertion (RPE) were recorded at the end of the warm-up and K500. BLa, heart rate and RPE were generally higher after the INT than CON and SS warm-ups (P < 0.05). No differences in these parameters were found between conditions for the time trial (P > 0.05). RPE and changes in BLa and heart rate after the K500 were comparable. There were no differences in K500 performance after CON, SS or INT warm-ups. Applied practitioners can, therefore, attain similar performances independent of the choice of warm-up type.

Keywords: Intermittent high-intensity, continuous, kayakers, acute performance, water sport, autoregulation.

1. Introduction

Individual sprint kayaking is contested over 500-m (K500) at both national and international levels [1]. At the 2019 U23 World Championships, male and female winners completed the event in 107.25 and 116.07 s, respectively [2]. These winning performances are executed by producing and maintaining the highest average boat velocity over the 500 m [3]. To achieve this, the kayaker must generate and sustain sufficient power output to overcome drag forces that act upon the kayak [4]. When competing in K500, high level female athletes sustain a power output that is around VO2peak (~45 ml.kg.min⁻¹) [5], suggesting the need for a high-power output at VO2peak. Despite the K500 event being deemed a sprint event the aerobic energy system contributes ~62% of the energy required [5–7]. Moreover, muscular strength and power, maximal aerobic power, and lactate threshold anaerobic capacity have been found to be predictors of sprint kayak performance [6,8,9].

Given the influence of these characteristics (i.e. lactate threshold, maximal aerobic power) on performance, athletes and practitioners have sought to improve them through longitudinal interventions [10–12]. For example, Liow and Hopkins [12] reported 2.3 to 3.4% improvements in
sprint performance after six weeks of heavy resistance training (~80% one repetition maximum). While such an approach can enhance performance, these changes take a prolonged period of time (i.e. weeks). Interventions such as warm-ups that can enhance performance acutely (i.e. within minutes) [18,19,21,23]. Therefore, it is important that practitioners use acute interventions, such as warm-ups, alongside longitudinal interventions to maximise performance.

A warm-up represents a stage of prior physiological or biomechanical activation incorporated to enhance athletic performance [14, 15]. Engaging in a warm-up may improve performance by increased intramuscular temperature, enhancing ATP resynthesis capacity, improving oxygen (O2) kinetics, increasing blood and O2 delivery to the muscles, and increasing nerve conduction velocity [13–17]. Consequently, a warm-up can induce a wide range of performance-related enhancements [18–20].

Regarding the effects of a warm-up on sprint kayak performance, the literature is limited to two studies [16,21]. Bishop et al. [16] compared three warm-up intensities (15 minutes continuous at aerobic threshold (~55% VO2max), at anaerobic threshold (~75% VO2max), or midway between aerobic and anaerobic threshold (~65% VO2max)) on a two-minute all-out kayak ergometer test. The average power in the first half of the test was lower after the anaerobic threshold warm-up than after the lower intensity warm-up [16]. It was suggested that acidemia associated with the more intense warm-up impaired performance [16]. In a subsequent study by Bishop and colleagues [21] a high-intensity, intermittent warm-up (10 mins at 65% VO2max followed by 5 x 10 s sprints at 200% VO2max, with 50 s active recovery) was associated with better two-minute all out sprint kayak performance than a continuous warm-up (15 mins at 65% VO2max). Whilst these findings are helpful for athletes and coaches, the studies are not without limitations: in races kayakers are unlikely to adopt an all-out pacing strategy but instead typically adopt an inverted J pacing strategy [8]. Indeed, Borges et al. [8] noted that the pacing strategy selected by a sprint kayaker was highly variable and dependent on race level, split distances and competitive seasons. Moreover, the two-minute all-out performance used by Bishop et al. [21] might not fully replicate K500, in regard to time. A study which investigates the effects of different warm-ups on K500 performance will aid practitioner confidence when prescribing warm-ups.

Despite the emerging literature on warm-up methods, the efficacy of a self-selected approach has received little attention. Bishop [15] suggests athletes who perform a warm-up of the same intensity and duration (e.g. a standardised group warm-up) may experience different effects upon performance. Therefore, it could be argued that warm-up duration, intensity and modality should be selected specifically for each athlete [22]. However, for applied practitioners working with multiple athletes this might not be feasible. It is plausible that experienced athletes, with sufficient training and competition experience, can self-select and therefore individualise, their own warm up. While the influence of a self-selected strategy on kayak performance has not been explored, limited research has investigated self-selected warm-up in other modes of exercise (i.e. [22,23]). Cyclists who self-selected their warm-up demonstrated a longer time to exhaustion on the cycle ergometer than those who used no warm-ups or two standardised warm-ups [22]. Some participants did perform better with a standardised warm-up than a self-selected [22], though this might be owing to the heterogenous sample (i.e. the sample consisted six team sport athletes, two middle-distance runners and one sprinter). Similarly, swimmers achieved a faster 50-yd freestyle time after performing their own self-selected warm-up than after a set warm-up [23]. Mechanistically, it is plausible that the self-selected warm-ups adopted previously [22,23] improve physiological and psychological preparedness for an athlete. Notwithstanding the mechanistic benefits, which are paramount, if athletes are able to self-select their warm-up effectively than, from a practitioner standpoint, this will provide an efficient method to enhance performance acutely. However, to date no study has determined if a self-select warm-up is an effective choice before a K500 time trial. Therefore, the aim of this study was to determine if experienced (i.e. national and international level) sprint kayakers can effectively self-select (SS) their own warm-up before a K500. To achieve this, we compared a SS
warm-up to continuous (CON) and intermittent, high-intensity (INT) warm-ups used previously [21].

A secondary aim was to report on the internal load experienced (i.e. blood lactate, heart rate and rating of perceived exertion) during these warm-ups and during the subsequent time trial performance. Given that dearth of comparable studies within sprint kayaking and different SS warm-ups, we propose the null hypothesis for both of our aims; 1) that there will be no differences between performance times and, 2) the internal load will not differ between warm-up modalities.

2. Materials and Methods

Participants

Twelve sprint kayak athletes with national and international experience (female = 3, 9 male), (age 17.7 ± 2.3 years, mass 69.2 ± 10.8 kg, stature 176.8 ± 7.4 cm), who were asymptomatic of illness and injury, were recruited by convenience sampling. All athletes were nationally ranked by British Canoeing in sprint category A-C, where the promotion criterion for the lowest category (C) is completing K500 in sub 132, 118, 144 and 134 s for boys, men, girls and women, respectively (table 1). All participants completed a pre-test health questionnaire and written informed consent. Assent was provided by parents/guardians for those under eighteen. Ethical approval was obtained from an institutional ethics committee.

Experimental design

The study employed a randomised repeated-measures design in which participants attended testing on four occasions (Figure 1). Each participant provided details of their SS warm-up prior to taking part in the study. In the initial visit, participants performed a graded exercise test until volitional exhaustion to determine the power at lactate threshold (LT; i.e. 2 m·mol⁻¹) and maximal oxygen uptake (VO2max). On subsequent visits, in a randomised order, participants completed a K500 ergometry test that was preceded by either a CON, SS or INT warm-up. Heart rate (Polar RS400, Kempele, Finland) and capillary blood lactate (BLa; HaB Direct, Warwickshire, UK), from the earlobe, were taken five-minutes prior to and immediately after each WU. Similarly, heart rate and BLa were taken immediately before and post K500. Ratings of perceived exertion (RPE) were measured using the Borg 6-20 scale immediately after each warm-up and K500 performance. Due to technical issues, heart rate data were only collected for eleven participants. Trials were separated by 24 hours and participants were asked to refrain from physical activity 24 hours prior to testing.

Figure 1. Schematic of study design. The warms ups were performed in a randomised order. Definitions are as follows: BLa = blood lactate, RPE = Rating of perceived exertion, HR = heart rate,
LT = lactate threshold, SS = self-selected warm up, INT = intermittent, high intensity warm up, CON = continuous warm up.

Procedures

Lactate threshold and maximal oxygen uptake

A graded exercise test was performed on a calibrated, wind-braked kayak ergometer (WEBA Sport, Wien, Austria) to determine the power (W) at LT and VO2max, for use in dictating warm-up intensities. Participants began at an initial workload of 50 W, with increments of 20 W for males and 15 W for females every four minutes until the athlete reached volitional failure or was unable to maintain required power output [24]. After each four-minute stage, a one-minute passive rest was used for BLa to be taken [16]. VO2max was identified by the highest consecutive fifteen seconds [24]. LT was identified at a fixed 2 m·mol⁻¹ value [24]. Expired gas samples were collected using a Cosmed K4b2 (Cortex Biophysik, GmbH, Leipzig, Germany). The gas analyser was calibrated prior to each test using a 4.87% CO2 and volume O2/Nitrogen 16.51/4.87% gas mixture and the volume sensor using a 3-L calibration syringe.

Warm-up procedures

- Continuous; participants performed a 15-minute warm-up at the power at LT. Participants were instructed to maintain a self-selected steady stroke rate (±3 strokes per minute) throughout the warm-up. This warm-up has been adopted previously [16,21].

- High-intensity, intermittent; for 10-minutes, participants performed steady state exercise at the power at LT. Thereafter, participants completed 5 x 10 s sprints at 200% VO2max with 50 s active recovery at 55% at VO2max. This warm-up has been adopted previously [16,21].

- Self-selected; participants completed a 15-minute SS warm-up that they would typically complete prior to competition. The full details of these can be found in Table 1.

During the warm-up, the participants were able to see their power and time on the kayak ergometer interfaced computer monitor. All warm-ups were followed by a five-minute passive recovery to replicate a competition and allow for sufficient recovery before completing the K500 [25]. In this time, participants remained seated. It must be acknowledged, athletes did not perform a familiarisation with INT and CON warm-ups however all participants were experienced sprint kayak athletes.
Table 1. Characteristics and individual warm-ups for each participant. PM denotes perceived maximum effort.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Ranking</th>
<th>Age</th>
<th>Mass (kg)</th>
<th>Stature (cm)</th>
<th>VO\textsubscript{\text{max}} (mL.kg.min\textsuperscript{-1})</th>
<th>Warm up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Men’s B</td>
<td>21</td>
<td>79</td>
<td>181</td>
<td>42</td>
<td>500m relaxed paddle, 3-4 x 20 stroke efforts</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>250m relaxed paddle, power strokes 250m, 3-5 x 30 stroke build up (10, 10, 10), 250m paddle, 1 x 10-30 stroke rolling start, 1 x 10-30 strokes standing start</td>
</tr>
<tr>
<td>2</td>
<td>Women’s B</td>
<td>18</td>
<td>75</td>
<td>186</td>
<td>32</td>
<td>500m relaxed paddle, 2 x standing starts, 2 x 40 stroke build-up of power same stroke rate upping every 10 until max on 40, 2 x standing starts.</td>
</tr>
<tr>
<td>3</td>
<td>Boy’s B</td>
<td>15</td>
<td>56</td>
<td>179</td>
<td>39</td>
<td>750m paddle with power strokes on/off, 200m paddle, 3 x 30 stroke starts.</td>
</tr>
<tr>
<td>4</td>
<td>Boy’s C</td>
<td>15</td>
<td>72</td>
<td>181</td>
<td>43</td>
<td>90s relaxed paddle, 3 x 30 at 70% PM rolling starts, 5 x 20 at 80% PM rolling starts, 2 x 20 at 90% PM, 1 rolling start and 1 standing start, 1 x 15 at 100% PM standing start.</td>
</tr>
<tr>
<td>5</td>
<td>Men’s B</td>
<td>20</td>
<td>76</td>
<td>180</td>
<td>39</td>
<td>3 x 30 strokes at 70% PM, 2 x 20 strokes at 80% PM, 1 x 20 strokes at 90% PM, 1 x 20 strokes at 95% PM.</td>
</tr>
<tr>
<td>6</td>
<td>Boy’s B</td>
<td>16</td>
<td>77</td>
<td>182</td>
<td>55</td>
<td>500m relaxed paddle, 3 x 30 strokes at 70% PM, 2 x 20 strokes at 80% PM, 2 x 20 strokes at 90% PM, 1 x 20 strokes at 100% PM, 2 build ups (10 strokes 70% PM, 10 strokes 80% PM, 10 strokes 90% PM, 5 strokes at 100% PM.</td>
</tr>
<tr>
<td>7</td>
<td>Boy’s A</td>
<td>16</td>
<td>51</td>
<td>165</td>
<td>65</td>
<td>500m relaxed paddle, 3 x 30 strokes at 70% PM, 20 strokes at 80% PM, 20 strokes at 80-90% PM, 10 strokes at 80% PM.</td>
</tr>
<tr>
<td>8</td>
<td>Men’s A</td>
<td>20</td>
<td>86</td>
<td>183</td>
<td>46</td>
<td>500m perceived LT threshold paddle, 3 x 30 strokes at 70% PM, 2 x 20 strokes at 80% PM, 1 x 20 strokes at 90% PM, 2-3 standing starts x 40 strokes.</td>
</tr>
<tr>
<td>9</td>
<td>Girl’s A</td>
<td>18</td>
<td>59</td>
<td>160</td>
<td>36</td>
<td>3 x 30 strokes at 70% PM, 2 x 20 strokes at 80% PM, 1 x 20 strokes at 90% PM, 1 x 30 strokes at 70% PM, 1 x 20 strokes at 95% PM, 1 x 30 strokes at 70% PM.</td>
</tr>
<tr>
<td>10</td>
<td>Men’s A</td>
<td>21</td>
<td>79</td>
<td>179</td>
<td>50</td>
<td>2 x 30 strokes at 70% PM, 2 x 25 strokes at 80% PM, 2 x 15 strokes at 95% PM, 2 x standing starts.</td>
</tr>
<tr>
<td>11</td>
<td>Girl’s C</td>
<td>15</td>
<td>61</td>
<td>171</td>
<td>38</td>
<td>500m relaxed paddle, 3 x 30 strokes at 70% PM, 2 x 20 strokes at 80% PM, 2 x 20 strokes at 90% PM, 1 x 20 strokes at 100% PM, 2 build ups (10 strokes.</td>
</tr>
</tbody>
</table>
Time trial performance

The participants completed a 500-m time trial on the same ergometer five minutes after each warm-up procedure. All participants used a kayak ergometer as part of their training regimes. Participants were asked to start with tension on one blade to replicate the normal starting position on the water and to complete the time trial in the shortest time they could. The foot bar position on the ergometer was adjusted to resemble the participant’s own boat set up, and bungee cord tension was adjusted manually to accommodate increased stroke rate [24,26]. No information was provided regarding a pacing strategy to use. Distance was visible on the kayak ergometer monitor as they would be aware of this in competition but not the power output, cadence or time. Participants were only given their performance times on completion of the study.

Statistical analysis

Data were checked for normality and equal variances by the Shapiro-Wilk and Levene statistics, respectively, and these assumptions were repeatedly found to be satisfied (P > 0.05). A one-way analysis of variance (ANOVA) was used to determine differences in RPE and time trial performance across warm-up conditions. Separate two-way repeated measures ANOVAs (warm-up type by time) were employed to determine difference in HR and BLa over the warm-up and time trial. When sphericity was violated, the Greenhouse-Geisser correction was used. Where necessary, post hoc t tests were used to locate differences in specific pairwise comparisons. Between-[(mean change condition/group 'a' – mean change condition/group 'b') / pooled weighted standard deviation of the change score] and within-condition/group (difference between means/pooled weighted standard deviation) effect sizes (ES; Hedges’ g) [27] and 90% confidence intervals (CI) were calculated to determine the size of the changes between conditions, allowing for a more practical and meaningful explanation of the data. Hedges’ g has been used over Cohen’s d as it typically better at reducing bias for smaller sample sizes. Thresholds for the magnitude of the observed change for each variable qualified as trivial (< 0.20), small (0.20 to 0.59), moderate (0.60 to 1.19), large (1.20 to 1.99), and very large (>2.00) [28]. Alpha was set at 0.05.

3. Results

Internal load during the warm-up

Comparing the values pre and post warm-up, a two-way repeated measures ANOVA revealed effects for warm-up (F = 8.0, P = 0.003), time (F = 18.6, P = 0.001) and warm-up by time (F = 6.5, P = 0.006) on BLa (Table 2). Post hoc analysis demonstrated significant increases in BLa after the warm-up for the CON (t = -5.1, P < 0.001) and INT (t = -4.5, P = 0.001) but not SS (t = -1.7, P = 0.120). Notably, moderately greater increases in BLa were observed after INT versus SS (ES = 0.91 ± 0.71) and CON (ES = 0.73 ± 0.71) warm-ups. Differences in BLa changes between CON and SS conditions were trivial (ES = 0.19 ± 0.67).

Effects of warm-up (F = 0.7, P = 0.504) and warm-up by time (F = 2.0, P = 0.174) were non-significant for heart rate for the same period, though there was a main effect for time (F = 84.7, P < 0.001). Increases in heart rate after the warm-up were significant for CON (t = -7.2, P = 0.001), SS (t = -5.3, P = 0.001) and INT (t = -8.6, P = 0.001) conditions. The differences in changes in heart rate between conditions were trivial for CON versus INT (ES = 0.16 ± 0.69) and moderate for CON versus SS and INT versus SS (ES = 0.74 ± 0.74, ES = 0.67 ± 0.72) comparisons.

A one-way ANOVA identified differences in RPE after the warm-up between conditions (F = 13.2, P < 0.001; Figure 3), whereby differences were significant for all comparisons. Notably, RPE was
higher after INT than CON \((t = -2.3, P = 0.04, ES = -0.65 \pm 0.69)\) and SS \((t = -4.5, P = 0.001, ES = 1.78 \pm 0.79)\) and for CON than SS \((t = 3.1, P = 0.01, ES = 1.13 \pm 0.73)\).

**Table 2.** Blood lactate and heart rate values (mean ± SD) pre and post warm-up for continuous (CON), self-selected (SS) and intermittent, high-intensity (INT) conditions. *denotes a significant different from pre to post within-condition \((P < 0.05)\).

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
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<tbody>
<tr>
<td><strong>CON</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLa (mmol.L(^{-1}))</td>
<td>1.1 ± 0.2</td>
<td>2.0 ± 0.6*</td>
</tr>
<tr>
<td>Heart rate (BPM)</td>
<td>63.7 ± 3.5</td>
<td>108.6 ± 18.8*</td>
</tr>
<tr>
<td><strong>SS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLa (mmol.L(^{-1}))</td>
<td>1.1 ± 0.2</td>
<td>1.8 ± 1.3</td>
</tr>
<tr>
<td>Heart rate (BPM)</td>
<td>66.1 ± 12.0</td>
<td>96.7 ± 9.4*</td>
</tr>
<tr>
<td><strong>INT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLa (mmol.L(^{-1}))</td>
<td>1.1 ± 0.3</td>
<td>3.3 ± 1.6*</td>
</tr>
<tr>
<td>Heart rate (BPM)</td>
<td>67.2 ± 8.8</td>
<td>107.7 ± 18.2*</td>
</tr>
</tbody>
</table>

**Time trial performance**

Figure 2 displays the mean and individual values for the time trial after each warm-up. There were no differences in time trial performance \((128.0 ± 14.6, 125.7 ± 11.7 and 128.2 ± 13.3\ s\) for CON, SS and INT, respectively) between conditions \((F = 2.3, P = 0.150)\). The magnitude of the differences between all comparisons was trivial \((ES = 0.19 ± 0.67, 0.19 ± 0.67 and 0.02 ± 0.67 for CON vs SS, SS vs INT and CON vs INT, respectively)\).

![Figure 2](image_url)

**Figure 2.** Sprint kayak time trial performance after continuous (CON), self-selected (SS) and intermittent, high-intensity (INT) warm-up. For comparative purposes, grey lines connect the individual times for each participant. The black rectangle denotes the average of each condition.

**Internal load during the time trial**

There was a main effect of time and time trial by time on BLa \((F = 70.1, P < 0.001\) and \(F = 3.9, P = 0.035\), respectively) and heart rate \((F = 31.1, P < 0.001\) and \(F = 5.5, P = 0.012\), respectively; Table 3) \(t\) paired sample \(t\)-test demonstrated increases in BLa and heart rate for CON \((t = -5.9, P < 0.001\) and \(t = -4.2, P = 0.002\), respectively), SS \((t = -8.6, P < 0.001\) and \(t = -4.7, P = 0.001\), respectively) and INT \((t = -6.4, P < 0.001\) and \(t = -3.9, P = 0.002\), respectively). The differences in changes in BLa were moderate for CON
and SS (ES = 0.59 ± 0.68) and SS and INT (ES = 0.83 ± 0.70) comparisons but trivial for the CON versus INT (ES = 0.19 ± 0.67). Post hoc analysis demonstrated significant increase in heart rate from pre to post time trial in the CON (t = -4.2, P = 0.002), SS (t = -4.7, P = 0.001) and INT (t = -3.9, P = 0.002) warm-ups. INT versus SS (ES = 0.67 ± 0.72) and CON versus SS (ES = 0.59 ± 0.68) heart rate showed differences in change scores that were small-moderate. The comparison between CON and INT revealed trivial differences (ES = 0.19 ± 0.67).

**Figure 3.** Ratings of perceived exertion (mean ± SD) after the warm-up and time-trial for continuous (CON), self-selected (SS) and intermittent, high-intensity (INT) conditions. *denotes significantly different from SS (P < 0.05). # denotes significantly different from CON (P < 0.05).

One-way ANOVA revealed no differences between post time trial RPE for each condition (P = 0.171). Indeed, the magnitude of the effects between CON versus SS, SS versus INT and CON versus INT were small (ES = 0.22 ± 0.67, 0.59 ± 0.68 and 0.38 ± 0.68, respectively).

**Table 3.** Blood lactate and heart rate values (mean ± SD) pre and post time trial for continuous (CON), self-selected (SS) and intermittent, high-intensity (INT) conditions. *denotes a significant different from pre to post within-condition (P < 0.05).

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CON</strong></td>
<td><strong>BLa (mmol.L⁻¹)</strong></td>
<td>1.9 ± 0.5</td>
</tr>
<tr>
<td></td>
<td><strong>Heart rate (BPM)</strong></td>
<td>102.4 ± 16.1</td>
</tr>
<tr>
<td><strong>SS</strong></td>
<td><strong>BLa (mmol.L⁻¹)</strong></td>
<td>1.7 ± 1.4</td>
</tr>
<tr>
<td></td>
<td><strong>Heart rate (BPM)</strong></td>
<td>95.8 ± 13.1</td>
</tr>
<tr>
<td><strong>INT</strong></td>
<td><strong>BLa (mmol.L⁻¹)</strong></td>
<td>3.2 ± 1.6</td>
</tr>
<tr>
<td></td>
<td><strong>Heart rate (BPM)</strong></td>
<td>100.4 ± 21.5</td>
</tr>
</tbody>
</table>

**4. Discussion**

This study compared the effectiveness of a self-selected warm-up on 500-m sprint kayak performance in experienced athletes with that of two standardised warm-ups. K500 time trial performance after a
SS warm-up was not different to that after a CON or INT warm-up. Moreover, the changes in internal load markers (blood lactate, heart rate and RPE) were similar after time trial performance. Therefore, sprint kayakers, competing in the K500, can attain similar performance with a variety of warm-ups. Practically, coaches may wish for athletes to SS their warm-up, as it likely that this is more efficient.

The CON and INT warm-ups resulted in greater increases in BLa than the SS warm-up. These findings are supported by previous observations of increased BLa after CON and INT type warm-ups [16,21]. Like these reports, the increase in BLa was greater for those warm-ups performed at a higher intensity (i.e. INT > CON). To our knowledge, no study has examined changes in BLa after a SS warm up. Nonetheless, the higher BLa data indicates that the glycolytic pathway has been used to a greater extent during the INT and CON conditions than SS. The elevations in heart rate over the course of the warm-up were generally similar between conditions. This is in contrast to Bishop and colleagues [16], who reported increases in heart rate that followed the intensity of the warm-up; a higher intensity warm-up raised heart rate to a greater extent. Similarly, Balilionis et al. [23] found that a SS swim warm-up resulted in greater increases in heart rate than a standardised warm-up (50 yards at 40% of swimmers’ maximal effort and 50 yards at 90%). However, our data are comparable to those of Mandengue et al. [22] who noted similar changes in heart rate irrespective of warm-up intensity. The comparable changes in heart rate in our study would suggest similar alterations in cardiac sympathetic and parasympathetic activity which aim to deliver oxygen to the working musculature [29]. Like BLa, athletes perceived exertion followed a similar pattern i.e. INT > CON > SS. Balilionis et al. [23] reported a higher RPE after a SS warm-up than a short standardised warm-up. Notably, the standardised warm-up provided by Balilionis and colleagues [23] consisted of only 90 m swimming, whereas participants SS warm-up was typically performed over ~1300 m. Nonetheless, the differences in RPE between conditions suggests different levels of motor command to the working muscles across the different warm-ups [30]. Collectively, these internal load data in this investigation would suggest that the internal load for the INT warm-up was greater than the CON and SS warm-ups.

This is the first study to investigate the effect of a SS warm-up on sprint kayak performance. Despite differences in the intensity (as noted by the differences in the internal load) and types, sprint kayak performance was similar after the warm-up conditions. Our data are in contrast to that of Bishop and colleagues [21] who observed enhanced power outputs during a 2 min all-out sprint kayak test after an INT warm-up compared to a CON one. The reason for the differences between our findings and those of Bishop et al. [21] are unclear but might reflect differences in the nature of an all-out test versus a time trial. Specifically, the pacing strategies of sprint kayakers are highly variable during a time trial and likely reflect an inverted-J strategy rather than an all-out one [8]. Nonetheless, the changes in BLa and heart rate were greater in the SS condition than CON and INT, though this was not reflected in the RPE scores which were comparable between conditions. That the internal load was generally lower during the WU but greater after the time trial in the SS condition than CON and INT, might suggest that when SS their warm-up sprint kayakers ‘paced/spared’ their aerobic or anaerobic capacities [14,15,21]. However, this potential pacing/sparing was not manifested in an improved time trial performance in this study. Holistically, these data would suggest that experienced sprint kayakers can perform the K500 using a variety of warm-up strategies. However, given the potential psychological preparedness that a SS warm-up might have [14,25], practitioners may wish to prescribe this warm-up.

This study was performed in the laboratory setting on a kayak ergometer and does not fully mirror the demands of on-water paddling but does simulate the physiological demands of short-term, high intensity kayaking; this choice, however, removed confounding factors such as differences in wind and temperature between days [31]. Moreover, we did not include a condition without a warm-up and therefore our data compared warm-ups rather than investigating their performance-enhancing effects per se. Nonetheless, from our perspective, it is highly unlikely that a national or international level athlete will compete without performing a warm-up. Readers should be aware
that whilst we included national and internationally ranked kayakers, our sample was not homogenous in the sense that the sample was mixed sex and included a variety of ages. However, our data still provides novel insights into the use of self-selected warm ups for sprint kayak warm ups in high level athletes. Future work may wish to address these limitations.

5. Conclusions

Sprint kayak performance was not significantly different after CON, SS and INT type warm-ups. Though there was some evidence (i.e. the attenuated internal load) that participants ‘paced/preserved’ their capacity during the SS warm-up compared to the CON and INT, this was not manifested in an enhanced performance. Applied practitioners may therefore prescribe a variety of warm-ups before sprint kayak performance. Practically, however, it might be more viable for athletes to perform their own self-selected warm-up.


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