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**Effects of 10 min vs. 20 min passive rest after warm-up on 100 m freestyle time-trial
performance: a randomized crossover study**

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51 **Abstract**

52 **Objectives:** The aim of this study was to compare the effect of 10min vs. 20min passive rest post
53 warm-up on performance in a 100 m freestyle time-trial.

54 **Design:** Randomized crossover.

55 **Methods:** Eleven competitive male swimmers performed two experimental trials on different days,
56 consisting of 100 m freestyle time-trials following 10min or 20min passive rest after a standard 1,200
57 m warm-up. Performance (time-trial), biomechanical (stroke length, stroke frequency, stroke index,
58 propelling efficiency), physiological (blood lactate concentrations, heart rate, core and tympanic
59 temperature), and psychophysiological (perceived effort) variables were assessed during both trials.

60 **Results:** Time-trial performance was faster after 10min as opposed to 20min passive rest (58.41 ± 1.99 s
61 vs. 59.06 ± 1.86 , $p < 0.01$). This was supported by strong effect sizes ($d = 0.99$) and the qualitative
62 indication of “likely” positive effects. Heart rate before the time-trial was also higher after 10 min
63 passive rest (89 ± 12 bpm vs. 82 ± 13 bpm; $p < 0.01$). Furthermore, net core temperature and oxygen uptake
64 values before the time-trial were substantially lower after 20min passive rest.

65 **Conclusions:** These data suggest that the 10min post warm-up passive rest enhances 100 m freestyle
66 performance when compared to a 20min period. An improvement that appears to be mediated by the
67 combined effects of a shorter post warm-up period on core temperature, heart rate and oxygen uptake.

68

69 **Keywords:** Sports Performance; Pre-exercise; Swimming; Heart Rate; Temperature.

70

71 **Introduction**

72

73 Warming-up before training or competition has become one of the most interesting topics for coaches,
74 swimmers and researchers in the last few years.¹⁻³ Studies have described physiological adaptations to
75 warm-up that theoretically support a positive effect of warm-up on subsequent performance; these
76 effects are mostly linked to an increase in body temperature.^{4,5} For instance, warm-up causes faster
77 oxygen dissociation from hemoglobin, acceleration of metabolic reactions and nerve conduction rate,
78 and reduced muscle and joint resistance.⁴ Besides the effects on body temperature, priming physical
79 activities might also exert additional effects that benefit performance, such as elevated baseline
80 oxygen uptake (VO_2) and increased amplitude of the primary VO_2 response to subsequent exercise.⁶

81

82 In swimming, it was only recently that evidence of the positive effects of warm-up on performance has
83 started to emerge. Studies found that swimmers were 1.5% faster in the 100m freestyle⁷ and were able
84 to apply 11.5% more propelling force during a 30s all-out freestyle when warm-up was performed.⁸
85 However, only a few studies have focused on the warm-up structure.^{1,2,9} The duration of the rest
86 interval separating the warm-up from the main high intensity task appears to be critical for subsequent
87 performance. It might seem obvious that one should aim to maintain the increased metabolic rate
88 achieved during warm-up,¹⁰ but in competition, a period of time is also needed to accomplish all
89 official requirements before the race. Zochowski et al.⁹ reported that 200m time-trial swim
90 performance was 1.38% faster after 10min passive rest compared to 45min. Using a longer rest period,
91 West et al.² verified that 200m time-trial swim performance times were 1.48% faster after a 20min
92 passive rest compared to 45min. Higher core temperature (T_{core})² and higher heart rate at the
93 beginning of the race, which potentially increased baseline oxygen consumption,⁹ were the main

94 mechanisms associated with the improved performance following shorter passive rest intervals. A
95 main limitation of these studies is the longer duration of the rest period used, i.e. 45 min, which might
96 even be too long to simulate a real competition. In addition, both studies focused on 200m time-trial
97 performance and did not measure VO_2 or biomechanical responses.

98

99 To the best of our knowledge, studies to date have only focused on the effects of different post warm-
100 up intervals in the 200m race, assessing few physiological parameters and disregarding hypothetical
101 biomechanical responses. Moreover, other racing distances might demand different passive rest
102 periods. For instance, the 100m freestyle involves a different use of metabolic pathways, with a lower
103 aerobic contribution than the 200m and perhaps less dependence on higher pre-trial VO_2 .²⁹ In addition,
104 the majority of studies investigating the effects of warm-up on swimming performance have used a
105 standard 10min interval, but their findings can only be fully understood if one knows how different
106 recovery periods could influence the results. Therefore, the aim of the present study was to compare
107 the effects of two different post warm-up intervals (10 and 20min rest) on 100m freestyle
108 performance. Performance, biomechanical, physiological and psychophysiological responses were
109 investigated. It was hypothesized that the shorter passive rest period would result in better swimming
110 performance.

111

112 **Methods**

113

114 Eleven competitive male swimmers (age 17.4 ± 1.8 years; height 176.4 ± 5.7 cm; body mass 65.7 ± 9.4 kg)
115 took part in this study. Swimmers were eligible for the study if they had competed at the national level
116 for the previous 6 years. In the current season, the swimmers trained with 36390 ± 5960 m per week
117 during 6 to 9 training sessions/week; the average personal best time in the 100m freestyle was $57.92 \pm$
118 2.05 s (534.4 ± 56.8 FINA 2015 scoring points). After university ethics committee approval, ensuring
119 compliance with the Helsinki declaration, participants were informed about the study procedures, and
120 written informed consent and/or assent forms were obtained.

121

122 The study followed a repeated measures design. Each participant completed 2 time-trials of 100m
123 freestyle, in randomized order, separated by 48hr. Swimmers were asked to wear the swimsuits they
124 normally wore during competitions. All the experiments were conducted two months after the
125 beginning of the season, at the same time of day (8:00–13:00 AM) in a 50m indoor swimming pool
126 with water temperature of $27.6\pm 0.1^{\circ}\text{C}$, air temperature of $27.9\pm 0.1^{\circ}\text{C}$ and $60.7\pm 0.2\%$ humidity. The
127 swimmers were familiarized with the warm-up procedures 48hr before the experiments and they were
128 reminded to maintain the same training, recovery and diet routines, including abstaining from caffeine,
129 during the 48hr prior to testing.

130
131 After arriving at the pool, the swimmers remained seated for 5min for the assessment baseline heart
132 rate (Vantage NV; Polar, Lempele, Finland), tympanic temperature (Braun Thermoscan IRT 4520,
133 Germany), Tcore (CorTemp, HQ Inc, Palmetto, FL) blood lactate concentration ($[\text{La}^-]$; Accutrend
134 Lactate[®] Roche, Germany) and VO_2 (Kb4², Cosmed, Rome, Italy). After that, the swimmers performed
135 a standard warm-up for a total volume of 1,200m (Table1), designed based on research^{7,9,10} with the
136 help of an experienced national swimming coach.

137
138 With the main set, the aim was to increase VO_2 to optimize the subsequent time-trial performance. It
139 was structured based on the assumptions that i) critical velocity could be faster than lactate threshold
140 and maximal lactate steady state, causing a progressive increase in VO_2 and $[\text{La}^-]$;¹¹ and ii) the rest
141 period should be sufficient to maintain $[\text{La}^-]$ levels lower than $5 \text{ mmol}\cdot\text{l}^{-1}$, as recommended for warm-
142 up procedures.¹³ The critical velocity was calculated from the slope of the regression line between
143 distance swam and time, combining the 50m and the 400m best times.¹¹ The range of critical velocity,
144 between 98 to 102%, corresponded to $85\pm 2\%$ and $88\pm 2\%$ of the 100m race-pace, respectively. Heart
145 rate, VO_2 and rating of perceived exertion¹² (RPE) were monitored during warm-up to ensure the same
146 intensity between the two trials. Once swimmers finished warming-up, they were asked to remain
147 seated for 10 or 20min before performing the 100m time-trial.

148

149 -Please insert Table1.

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Each swimmer was instructed to step onto the starting block and then take off after official verbal command and the starting signal. Trial times were clocked by a timing system (OMEGA S.A. Switzerland), using as backup a stopwatch held by a swimming coach and a video camera (Casio Exilim Ex-F1, $f=30$ Hz) placed at 15m, perpendicular to lane 7. That same procedures and devices were also used to assess the 15m time. Stroke frequency (SF), stroke length (SL) and stroke index (SI) were determined according to the procedures reported earlier by Neiva et al.⁷ The propelling efficiency (η_p) was also estimated¹⁴:

$$\eta_p = [(0.9 \cdot v) / (2\pi \cdot SF \cdot l)] \cdot 2/\pi$$

where v is the swimming velocity (m s^{-1}), SF is the stroke frequency (Hz) and l is the arm length (m). The l is computed trigonometrically by measuring arm length and considering average elbow angles during insweep of the arm pull, as reported by Zamparo et al.¹⁴ At the range of swim velocities demonstrated in these swimmers, internal mechanical work is rather low and can be neglected¹³ and η_p becomes similar to Froude efficiency. For a more detailed discussion, see Zamparo et al.¹⁴

Capillary blood samples for $[\text{La}^-]$ assessment were collected from the fingertip after the warm-up protocol (1min), immediately before the trial, after the trial (3 and 6min after to obtain the highest value) and 15min after the trial. Heart rate was also assessed over the warm-up period and during recovery following the time-trial. Additionally, the RPE was recorded during and after the warm-up, and after each trial.

Tympanic temperatures were measured before the warm-up, after the warm-up (1min), immediately before and after the trial and 15min post-trial. Tcore was assessed by a temperature sensor that was ingested the night before (10hr before the test).¹⁵ This pill transmitted a radio signal to an external sensor (CorTemp Data Recorder, HQ Inc., Palmetto, FL), which subsequently converted the signal into digital format. The net values of Tcore ($T_{\text{core,net}}$) were selected to compare data and reduce error resulting from pill position.

178 VO_2 was measured with a backward extrapolation technique immediately after trial.¹⁶ The first 2s of
179 measurement after detection were not considered due to the device's adaptation to the sudden change
180 of respiratory cycles and to oxygen uptake.¹⁷ The peak oxygen uptake ($\text{VO}_{2\text{peak}}$) was considered to be
181 the mean value of the following 6s.¹⁷ Additionally, VO_2 was continually monitored during the post
182 warm-up time period and after the 100m freestyle.

183
184 Standard statistical procedures were selected for the calculation of means, standard deviations (SD)
185 and confidence limits. The normality of all distributions was verified by the Shapiro-Wilks test, and
186 parametric statistical analysis was adopted. To compare data between two trials, Student's paired t-
187 tests were used, followed by Cohen's d effect size for repeated measures ($p \leq 0.05$). The effect size was
188 calculated using G-Power 3.1.3 for Windows (University of Kiel, Germany) and 0.2 was deemed
189 small, 0.5 medium, and 0.8 large. An Excel spreadsheet for crossovers was used to calculate the
190 smallest worthwhile effects and to determine the likelihood that the true effect was substantially
191 harmful, trivial, or beneficial (positive, trivial or negative for non-performance variables).¹⁸ The
192 threshold value for the smallest worthwhile change was set at 0.8% for performance, whereas the other
193 variables were set at 0.2 (Cohen's smallest effect size).¹⁸ Suggested default probabilities for declaring
194 an effect clinically beneficial were $<0.5\%$ (most unlikely to harm) and $>25\%$ (possible benefit).¹⁹ The
195 effect was deemed unclear if it was possibly beneficial ($>25\%$) with an unacceptable risk of harm
196 ($>0.5\%$). Where clear interpretation could be made, chances of benefit or harm were assessed as
197 follows: $<0.5\%$, most unlikely, almost certainly not; 0.5-5%, very unlikely; 5-25%, unlikely, probably
198 not; 25-75%, possibly; 75-95%, likely, probably; 95-99.5%, very likely; and $>99.5\%$, most likely,
199 almost certainly.¹⁹

200

201 **Results**

202

203 Performance was improved moderately in the 10min compared to the 20min rest condition (Table 2),
204 resulting from a large effect on the first 50m lap and a moderate effect on the second 50m lap. The
205 swimmers categorised their effort as being between very hard and exhaustive in both trials ($p=0.18$;

206 $d=0.55$; mean difference 1.0%; 90% confidence limits ± 2.9 ; clinical inferences unclear). Regarding the
207 biomechanical analysis (Table 2), the swimmers showed higher SF after 10min passive rest during the
208 first 50m lap, with small effect sizes seen in the second 50m. Despite the unclear implications of SL
209 and η_p in the first 50m, there were clear decreases in SI, SL and η_p during the second 50m lap.

210

211 -Please insert Table2.

212

213 Figure 1 depicts the physiological responses to the different conditions. Baseline measures of Tcore
214 (1A) were similar between conditions ($p=0.27$; $d=0.46$; 0.8%; ± 1.2 ; unclear). The highest Tcore values
215 were recorded after warm-up (10min $37.67 \pm 0.48^\circ\text{C}$; 20min $37.76 \pm 0.57^\circ\text{C}$). There was a small
216 additional decrease in Tcore in the 20min compared to the 10min passive rest ($p=0.78$; $d=0.11$; -0.1%;
217 ± 0.9 ; possibly negative), corroborated by pre-trial Tcore_{net} differences ($p=0.31$; $d=0.32$; -55.3%;
218 ± 19.1 ; possibly negative). Those differences in Tcore_{net} (1B) were increased after the trial ($p=0.16$;
219 $d=0.59$; -66.2%; ± 12.0 ; likely negative). The 15min of recovery were not sufficient to return to
220 baseline values ($37.46 \pm 0.33^\circ\text{C}$; $37.36 \pm 0.39^\circ\text{C}$). The tympanic temperature (1C) recorded no clear
221 differences between conditions until the end of trial, when medium differences were found ($p=0.06$;
222 $d=0.49$; -1.4%; ± 1.5 ; likely negative), and after recovery ($p=0.06$; $d=0.70$; -0.9%; ± 0.8 ; likely
223 negative).

224

225 Baseline measures of $[\text{La}^-]$ (1D) were low and similar between conditions ($p=0.16$; $d=0.46$; 8.1%;
226 ± 9.7 ; likely trivial). $[\text{La}^-]$ responded in the same way to warm-up ($p=0.20$; $d=0.44$; 5.5%; ± 8.8 ; most
227 likely trivial). $[\text{La}^-]$ attained the highest values after trial, but no clear differences were observed
228 ($11.91 \pm 3.82 \text{ mmol}\cdot\text{l}^{-1}$ vs. $11.32 \pm 3.71 \text{ mmol}\cdot\text{l}^{-1}$; $p=0.36$; $d=0.29$; -4.9%; ± 12.2 ; unclear), and this was
229 maintained during recovery ($p=0.18$, $d=0.43$; -10.9%; ± 13.6 ; possibly negative).

230

231 There was a small difference in baseline heart rate (1E) between the two protocols ($p=0.13$; $d=0.49$;
232 3.3%; ± 3.6 ; possibly negative) but similar VO_2 (1F) ($p=0.78$; $d=0.11$; -0.4%; ± 2.3 ; very likely trivial).

233 The response to warm-up was identical between conditions for both heart rate ($p=0.73$, $d=0.40$; -0.8%;

234 $\pm 3.6\%$; likely trivial) and VO_2 ($p=0.82$, $d=0.09$; 4.0% ; ± 21.7 ; unclear). This data corroborates the
235 similarity between the warm-up intensities and procedures, as evidenced by the perceived effort after
236 warm-up (10.00 ± 1.48 vs. 9.55 ± 1.63 ; $p=0.45$; $d=0.25$; 6.7% ; ± 14.8 ; unclear). However, pre-trial values
237 showed lower heart rates in the 20min condition (89 ± 12 bpm vs. 82 ± 13 bpm; $p < 0.01$; $d=1.07$; -7.8% ;
238 $\pm 4.0\%$; very likely negative). This may somehow reflect the near statistically significant difference
239 between VO_2 pre-trial, but with a high effect size ($8.58 \pm 1.67 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ vs. $7.54 \pm 2.45 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$;
240 $p=0.07$; $d=0.81$; -14.1% ; ± 10.5 ; likely negative). After the trial, no clear differences were seen in
241 $\text{VO}_{2\text{peak}}$ ($55.23 \pm 7.03 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ vs. $53.67 \pm 9.46 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$; $p=0.39$; $d=0.35$; -3.4% ; ± 5.9 ; possibly
242 negative), while lower heart rates were found in the 20min passive rest condition (173 ± 6 bpm vs.
243 165 ± 11 bpm; $p=0.10$; $d=0.75$; -4.7% ; ± 4.5 ; likely negative). A greater additional decrease in heart rates
244 for the 20min condition was found during recovery ($p=0.004$; $d=1.11$; -9.0% ; ± 4.3 ; very likely
245 negative).

246

247 -Please insert Figure 1.

248

249 **Discussion**

250

251 The aim of this study was to compare the effects of 10min or 20min post warm-up passive rest on
252 100m freestyle performance in competitive swimmers. The main finding was a “likely” positive effect
253 on swimming performance when the shorter passive rest period was used (1.12% faster time-trial
254 performance with 10min vs. 20min). This supported the hypothesis that a shorter time-lag between the
255 warm-up and the race benefits time-trial performance. The physiological response may partially
256 explain this finding. Although acute adaptations in body temperature did not seem enough to justify
257 the difference in performance, the combined effects of the shorter post warm-up interval on T_{core} ,
258 heart rate, and VO_2 appeared to be associated with the faster performance observed.

259

260 Active warm-up in swimming seems to improve performance after rest periods of 10min⁹ and 20min.²

261 However, it remains to be seen which duration is the most effective for optimizing performance and

262 which type of rest (active or passive) should be used.²⁰ It has been suggested that increases in muscle
263 and core temperature caused by priming exercises are the major factors influencing performance.⁴ At
264 least for land-based activity, an increase in the athlete's temperature results in lower time required to
265 achieve peak tension and relaxation,²¹ reduced viscous resistance of the muscles and joints,²² increased
266 muscle blood flow,²³ improved efficiency of muscle glycolysis and high-energy phosphate
267 degradation,²⁴ and increased nerve conduction rate.⁵ Therefore, we implemented a recommended
268 warm-up volume,¹⁴ including a near race-pace velocity set¹⁴ (approximately 90% of the 100m race-
269 pace velocity), that resulted in increased VO_2 and body temperature.

270
271 In the present study, as expected, T_{core} increased during the warm-up, eventually reaching its
272 maximum value, and then started to drop, decreasing up until the beginning of the time-trial. Before
273 the race, the 20min rest interval had a very "likely" negative effect on $T_{\text{core}_{\text{net}}}$ values. Therefore, the
274 lower $T_{\text{core}_{\text{net}}}$ in the 20min condition could have influenced the swimmers' performance, as a
275 decrease in performance could be related to muscle and core temperature decline after exertion.²⁵
276 Despite not being significant, tympanic temperature recorded a trend towards higher values in the
277 10min condition, supporting the $T_{\text{core}_{\text{net}}}$ data. West et al.² noted that 45min was an excessive rest
278 period for the T_{core} , explaining its negative effect on 200m freestyle performance. In this study, the
279 abovementioned effects on T_{core} cannot by themselves explain the 1.12% performance improvement;
280 the pre-trial heart rate and VO_2 data can provide complementary support, as the 10min of extra rest in
281 the 20min condition lowered these variables by ~8% and ~14%, respectively. Thus, the strong effect
282 verified in these two variables could influence the race, notably during the first few meters.

283
284 After verifying a higher heart rate before the 200m trial in the 10min rest compared with the 45min
285 rest, Zochowski et al.⁹ hypothesized that the swimmers started the trial at a high baseline VO_2 . The
286 authors did not measure the VO_2 , but our data confirmed their speculation for both heart rate and VO_2 .
287 Before their study, warm-up was already believed to increase VO_2 and oxygen kinetics.⁶ Yet, our
288 study was the first to provide evidence of such. Higher baseline VO_2 might have influenced the energy
289 provision from anaerobic sources in the first part of the race by increasing the aerobic contribution and

290 preserving the high-energy substrates for later use in the task.²⁶ This might explain the ~0.7% faster
291 times in the second lap in the 10min condition compared to the 20min condition.

292

293 The better performance seen in the first 50m lap after a 10min post warm-up period could be the result
294 of higher SF. The swimmers were able to reach higher SF due to an effect on motor neuron
295 excitability that remained after the shorter post warm-up rest.²⁷ Also, it could point to a post-activation
296 potentiation effect that should happen by the 8th min of recovery,²⁸ enabling an optimized SF. Thus,
297 increased SF for the same efficiency (monitored by the SI and η_p) resulted in a faster 50m lap.

298

299 The different post warm-up periods were not enough to cause differences in the $[La^-]$ after the trial.
300 Some authors may suggest that a shorter rest induces increased lactate production due to glycolytic
301 stimulation over the trial. However, the increased VO_2 at the beginning of the trial could have
302 stimulated the aerobic contribution, which has been shown to reach approximately 50% of the energy
303 expenditure in a 100m maximal bout.²⁹ Moreover, this could hinder the glycolytic pathway. Although
304 we failed to observe differences in $[La^-]$, VO_{2peak} and RPE, the increased heart rate seen after the trial
305 might suggest a higher spike in such variables at the beginning of the trial. An increased primary
306 response would increase the oxidative metabolic contribution early in the exercise and increase
307 anaerobic metabolism in the final meters.²⁶ This could augment the heart rate response such that the
308 swimmers can easily recover their homeostasis.

309

310 Although muscle temperature could be an important complementary variable with which to better
311 understand our findings, we should not disregard T_{core} as having a great influence on performance.⁴
312 Recent findings about passive post warm-up heating strategies showed that some exertion was also
313 needed for better performance.^{10,30} Accordingly, our results suggested that temperature alone could not
314 be responsible for the performance optimization. Therefore, researchers should consider analysing the
315 in-water swimming sets so that the abovementioned effects can be extended. The lower values of VO_2
316 before the race in both trials lead us to speculate that some physiological adaptation mechanism may
317 occur to change the motor unit recruitment patterns, thus optimizing the immediate VO_2 response

318 during trial. We should also be aware of possible differences in the physiological measurements
319 between time-trials compared to competition. For instance, heart rates could be higher during pre-race
320 build-up due to increased anxiety from the competition itself. Nevertheless, we aimed to ensure that
321 the swimmers performed the two maximal trials in the same conditions.

322

323 **Conclusion**

324

325 The swimmers were faster in the 100m freestyle following 10min vs. 20min post warm-up passive
326 rest. Despite the expected influence of body temperature in this improvement, our data suggests that
327 temperature is not the only influencing factor. Heart rate and VO_2 seem to be positively influenced by
328 the shorter rest, notably influencing the first meters of the race. This may increase the aerobic
329 contribution to this initial phase of the race, stimulating different metabolic energy pathways and
330 resulting in improved performance. Further research should focus on the passive or active methods of
331 rest for maintaining the benefits of warm-up (i.e. elevated temperature, heart rate and VO_2) during the
332 time frame between warm-up and the swimming race.

333

334 **Practical implications**

335

336 -The beneficial effects of in-pool warm-up may decrease over time and influence the subsequent
337 swimming race. It is suggested to conduct the warm-up close to the race to benefit from all of its
338 positive effects.

339

340 -The time-lag between warm-up and race should be long enough to allow a post potentiation effect,
341 but not so long that oxygen consumption, heart rate and core temperature effects disappear.

342

343 -Coaches should develop methods to maintain the swimmers' warm-up temperature (e.g. passive
344 warm-up) and perhaps some light activities to maintain heart rate and VO_2 above resting values before
345 the swimming race.

346

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348

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353

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428

429 **Figure Legends**

430

431 Figure 1. Physiological variables responses throughout the procedures: core temperature (A), net
432 values of core temperature (B), tympanic temperature (C), blood lactate concentrations ($[La^-]$; D),
433 heart rate (E), Oxygen uptake (VO_2 ; F). * Indicates difference between the two conditions assessed (p
434 < 0.01). Data presented as mean \pm SD (n=11).

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435 Table 1 – Standard warm-up (WU) protocol.

| WU | Task description |
|---------------|--|
| 300m | 100m usual breathing, 100m breathing in the 5 th stroke, 100m usual breathing |
| 4x100m @ 1:50 | 2x (25m kick - 25m increased stroke length) |
| 8x50m @ 1:00 | 98% - 102% of critical velocity (or 85-90% of 100m pace) |
| 100m | Easy swim |

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437

437 Table 2 – Mean \pm SD values of the 100 and 50m lap times, stroke frequency (SF), stroke length (SL),
 438 stroke index (SI), and propelling efficiency (η_p) with 10min and 20min post warm-up passive rest.
 439 Effect sizes (d), p-values, and inferences for percent change of means are presented (n=11).

| | 20-min vs. 10-min | | | | | | |
|--|-------------------|------------------|------|---------|-----------------------------------|---------------|-----------------------|
| | 10min | 20min | d | p-value | Mean % change; \pm 90%CL* | %Chance ** | Qualitative inference |
| 100m time-trial [s] | 58.41 \pm 1.99 | 59.06 \pm 1.86 | 0.99 | <0.01 | 1.1 \pm 0.6 | 80/20/0 | Likely harmful |
| 1 st 50m [s] | 27.72 \pm 0.92 | 28.15 \pm 0.73 | 1.13 | <0.01 | 1.6 \pm 0.8 | 95/5/0 | Very Likely harmful |
| 2 nd 50m [s] | 30.69 \pm 1.27 | 30.91 \pm 1.30 | 0.58 | 0.08 | 0.7 \pm 0.7 | 41/59/0 | Possibly harmful |
| 1 st 15m [s] | 7.13 \pm 0.33 | 7.26 \pm 0.19 | 0.51 | 0.14 | 1.8 \pm 1.9 | 81/17/2 | Likely harmful |
| 1 st 50m SF [Hz] | 0.87 \pm 0.07 | 0.85 \pm 0.06 | 0.66 | 0.05 | -3.2 \pm 2.6 | 0/16/84 | Likely -ive |
| 2 nd 50m SF [Hz] | 0.73 \pm 0.04 | 0.74 \pm 0.04 | 0.23 | 0.47 | 0.6 \pm 1.7 | 38/57/5 | Unclear |
| 1 st 50m SL [m] | 2.03 \pm 0.17 | 2.07 \pm 0.17 | 0.40 | 0.26 | 1.9 \pm 2.7 | 49/49/2 | Unclear |
| 2 nd 50m SL [m] | 2.19 \pm 0.14 | 2.16 \pm 0.17 | 0.39 | 0.24 | -1.3 \pm 1.9 | 1/52/46 | Possibly -ive |
| 1 st 50m SI [m ² c ⁻¹ s ⁻¹] | 3.60 \pm 0.37 | 3.61 \pm 0.35 | 0.06 | 0.86 | 0.3 \pm 2.7 | 11/83/6 | Likely trivial |
| 2 nd 50m SI [m ² c ⁻¹ s ⁻¹] | 3.51 \pm 0.32 | 3.44 \pm 0.38 | 0.49 | 0.14 | -2.0 \pm 2.2 | 0/42/57 | Possibly -ive |
| 1 st 50m η_p [%] | 33.88 2.45 | 34.55 2.34 | 0.41 | 0.20 | 2.0 \pm 2.7 | 61/37/2 | Unclear |
| 2 nd 50 η_p [%] | 36.55 1.91 | 36.10 2.37 | 0.36 | 0.26 | -1.3 \pm 1.9 | 2/44/54 | Possibly -ive |

90% CL = 90% confidence limits. +ive, -ive = positive and negative changes, respectively.

* where a positive % change equates to an increase in 20min condition

** presented as harmful/trivial/beneficial for performance (time) and positive/trivial/negative for other variables

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