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Title: Morning resistance exercise and cricket-specific repeated sprinting each improve indices of afternoon physical and cognitive performance in professional male cricketers

Running head: Morning priming in cricket

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Figures: 3

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1 **Abstract**

2 *Objectives:* To compare two modes (general and cricket-specific) of morning priming exercise on
3 afternoon physical and cognitive performance, and subjective readiness to perform in professional male
4 cricketers.

5 *Design:* Randomised, crossover, counterbalanced.

6 *Methods:* On three occasions, 16 professional men’s cricketers completed afternoon tests of
7 countermovement jump height, cricket-specific sprint performance (running between the wickets, two
8 runs), cognitive function (Stroop test, time taken), and subjective readiness to perform. Control (CON;
9 passive rest), lower-body resistance exercise priming (LIFT; trap bar deadlifts, 6 x 4 repetitions up to
10 85% of one repetition maximum), or cricket-specific running priming (RUN; 6 x 35.36 m sprints
11 including a 180° change of direction) interventions were implemented 5.5 h before testing.

12 *Results:* Afternoon sprint times were faster in RUN (-0.04 s, $p = 0.013$) and LIFT (-0.07 s, $p < 0.001$)
13 versus CON, and faster in LIFT than RUN (-0.03 s, $p = 0.032$). Jump height (+1.1 cm, $p = 0.021$) and
14 cognitive function (-3.83 s, $p = 0.003$) were greater in LIFT than CON, whilst RUN outperformed CON
15 for cognition (-2.52 s, $p = 0.023$). Although perceived readiness was not influenced by trial ($p > 0.05$),
16 players reported favourable responses on the “aggression” subscale in LIFT relative to CON (+1
17 arbitrary unit, $p = 0.022$).

18 *Conclusions:* Both general (lower-body resistance exercise) and cricket-specific (simulated running
19 between wickets) morning priming are effective match-day strategies to improve afternoon markers of
20 physical and cognitive performance in professional men’s cricketers. Practitioners may thus be afforded
21 flexibility in situations where resistance exercise is not feasible on the morning of a match.

22

23 **Key words**

24 Strength; Speed; Power; Potentiation, Preparation, Team sports

25

26

27

28

29 **Introduction**

30 Although cricket match-play involves mostly low-intensity activities, crucial moments require
31 explosive high-speed movements such as power hitting, sprinting, bowling, diving, and throwing.^{1,2}
32 For example, batters score by running 17.68 m from one crease to another (often multiple times in
33 succession, including turns), while horizontal velocity during a fast bowler's pre-delivery stride is
34 positively related ($r = 0.73$) to ball speed upon release.³ Fielders produce high-intensity efforts such as
35 dives, throws, and sprints to help save runs and take wickets.^{1,2} Cricketers also face substantial cognitive
36 demands, including anticipating and reacting to myriad environmental stimuli.^{4, 5} Limited-overs
37 matches in particular are often decided based on fine margins, each delivery potentially having a
38 meaningful impact on the match outcome.^{6,7}

39

40 Performing resistance exercise on the morning of competition could improve indices of afternoon
41 physical performance. Whilst several mechanisms such as increased joint stiffness, high-frequency
42 motor neuron activation, and greater muscle fibre sensitivity to calcium ions have been proposed to
43 contribute to such responses,⁸ a body of evidence suggests that hormonal changes likely play a
44 substantial role. Specifically, testosterone concentrations are positively associated with indices of
45 explosive physical performance in trained populations⁹⁻¹¹ and potentially influence other psychological
46 or behavioural responses such as motivation, confidence, and cognitive function.^{9, 12} Whereas
47 endogenous testosterone concentrations typically demonstrate diurnal variations, characterised by an
48 early morning peak followed by a transient decline through the day,^{13,14} resistance exercise may acutely
49 elevate testosterone.¹⁵ Such hormonal responses could enhance athletic performance if these elevations
50 are maintained at the onset of subsequent exercise.^{16,17}

51

52 Well-trained shot putters who performed back squats and power cleans in the morning produced greater
53 throwing performance 4-6 h later, compared with a rested condition.¹⁸ Similarly, semi-professional
54 rugby players improved afternoon strength, as well as jump and sprint performance, after completing
55 morning resistance training.¹⁶ Notably, priming offset circadian declines in salivary testosterone
56 concentrations that were otherwise observed.¹⁶ Although delayed potentiation or 'priming' effects could

57 exist for ~1-48 h following resistance exercise, the greatest benefits are realised between ~6-33 h after
58 the priming stimulus.⁸ However, several barriers including travel demands, and a lack of time or access
59 to facilities may often limit the feasibility of resistance exercise-based priming interventions as a
60 competition-day strategy.¹⁹ Indeed, a survey of high-performance sport practitioners suggested that
61 many respondents had never (19%) or no longer (30%) implemented priming exercise despite 84%
62 believing the practice to be efficacious.¹⁹

63

64 Russell et al.¹⁷ confirmed that more flexible modes of priming exercise could improve afternoon athletic
65 performance in professional rugby union players. Whilst morning resistance exercise improved repeated
66 sprint responses compared with a rested control condition, performing six 40 m sprints also improved
67 sprint times, and augmented jumping performance ~5 h later.¹⁷ Such findings may suggest a role for
68 alternative methods of morning priming (i.e., repeated sprinting) that could be more practically
69 achievable in an applied scenario. Further research is warranted to confirm this suggestion by examining
70 the role of priming specificity and assessing the potential for feasible modes of priming exercise to
71 benefit indices of sport-specific physical and cognitive performance in a broader range of athletic
72 populations. Indeed, resistance exercise has also been linked with acutely improving aspects of
73 cognitive function,²⁰ although the effects of exercise priming on cognitive responses remain unclear.¹⁷
74 This study aimed to examine the influence of two different modes of morning priming exercise on
75 indices of cricket-specific physical performance, cognition, and subjective readiness to perform in
76 professional men's cricketers.

77

78 **Materials and methods**

79 Following ethics approval from Swansea University Ethics Committee, 16 professional male
80 cricketers (age 26 ± 6 years, mass 88.1 ± 8.4 kg, stature 184.5 ± 3.6 cm) volunteered to
81 participate. All participants were healthy and injury-free and were informed of the risks and
82 benefits of participation before providing written consent prior to the study commencing.

83

84 Participants completed three trials in a randomised, counterbalanced, cross-over fashion. A no-priming
85 control condition and two priming interventions were each separated by at least seven days. Participants
86 were asked to maintain consistent nutritional practices and abstained from any caffeine, alcohol, and
87 physical training on the day of each trial and during the preceding 24 h. Participants arrived at the testing
88 venue in the morning of each trial and completed a standardised active warm-up, consisting of dynamic
89 stretching, activation work, and sprints of increasing intensity. Timings remained consistent between
90 trials to avoid the influence of diurnal variation in performance.¹⁴ The intervention stimulus followed
91 five minutes thereafter, whereby players completed either general lower-body resistance exercise
92 (LIFT) or a cricket-specific repeated sprint protocol (RUN) in the priming interventions. A control
93 condition (CON) involved no morning exercise.

94

95 For LIFT, participants performed one set of four repetitions of trap bar deadlifts at each of 50%, 70%,
96 80% of an individual's predicted one repetition maximum (1RM), before three sets of four repetitions
97 at 85% 1RM. Inter-set rest was 120 s. The RUN condition involved a cricket-specific repeated sprint
98 protocol, consisting of six sets of 35.36 m sprints, separated by 30 s passive rest. Each sprint required
99 a 180° change of direction after the first 17.68 m, which aligned with the standard England and Wales
100 Cricket Board (ECB) 'run-two' test.⁵

101

102 Participants rested for 5.5 h after the morning priming protocol. Players completed a subjective
103 readiness to perform questionnaire, before undertaking the standardised warm-up. The afternoon testing
104 battery followed thereafter; a Stroop test of cognitive ability and then two physical performance tests.
105 Testing was conducted at the team indoor practice facilities. Participants wore their normal indoor
106 training footwear and apparel, which remained consistent across trials. All participants and assessors
107 were familiar with testing and priming procedures as part of normal training and monitoring practices.

108

109 Subjective ratings of readiness were assessed via a scale adapted from Mason et al.²¹. Players
110 documented their perceived 'fatigue', 'aggression', 'soreness', 'mood', and 'motivation'. Each was
111 rated on a five-point Likert scale ranging from '1' (least) to '5' (most ready), to give a score for each

112 subscale and an overall readiness score.²¹ Higher scores indicated greater readiness. Questionnaires
113 were provided in paper format, which participants completed in isolation and without communication
114 with others. Cognitive function was then assessed via a Stroop test on a mobile tablet device
115 (EncephalApp, HindSoft, India), in which players were required to repeatedly identify the colour of
116 printed text appearing on different coloured backgrounds.

117

118 Physical performance was assessed via countermovement jumps (CMJ) and ‘run-two’ sprint tests. Each
119 CMJ commenced in a static standing position, from which participants performed a preparatory ‘dip’
120 before explosively jumping to attain maximum height. Arms remained akimbo, while jump height (JH)
121 was calculated from flight time data derived from photoelectric cells (Optojump, Microgate, Italy,
122 v1.12.1.). This technology has demonstrated excellent test-retest reliability (intraclass correlation
123 coefficient; ICC: 0.99, coefficient of variation; CV: 2.2%) for estimating vertical JH in physically active
124 individuals,²² while ICC of 0.99 has been reported in professional cricketers.²³ Participants performed
125 four repetitions on each occasion, with the greatest JH achieved being retained for analysis.

126

127 The ‘run-two’ is an established ECB standard test, designed to replicate completing two runs.
128 Participants sprinted 35.36 m whilst carrying a standard cricket bat, including a 180° turn after 17.68
129 m.⁵ Sprints commenced from 0.5 m behind the start line, where participants waited for the verbal start
130 command. Time taken to complete 35.36 m was recorded using electronic timing gates (Brower Timing
131 Systems, USA), with the fastest of three completed sprints being retained for analysis.²⁴ In professional
132 cricketers performing this test once per week, CV <1% and ICC of 0.99 have been reported,^{5, 25} while
133 the current sample have produced CV of 1.4% over three repetitions.

134

135 Statistical analyses were conducted using SPSS (Version 27; SPSS Inc., USA) with significance
136 established when $p < 0.05$. One-way repeated measures analyses of variance were used to determine
137 whether ‘trial’ influenced afternoon assessments of physical or cognitive performance. Mauchly’s test
138 was consulted, and the Greenhouse–Geisser correction was applied if the assumption of sphericity was
139 violated. Significant trial effects were further investigated using post-hoc Sidak-adjusted pairwise

140 comparisons. Between-trial differences in total readiness and scores for each readiness subscale were
141 assessed via Friedman's analyses of variance with pairwise post-hoc comparisons. Hedge's g effect
142 sizes (ES) were calculated for post-hoc comparisons, and were interpreted as trivial (0.00–0.19), small
143 (0.20–0.49), moderate (0.50–0.79), or large (>0.80).²⁶ Pearson's product moment correlations were
144 calculated to assess bivariate relationships between 1RM strength and changes in performance
145 following priming relative to CON. Data are reported as mean ± standard deviation unless otherwise
146 stated.

147

148 **Results**

149 Table 1 shows that trial influenced sprint performance ($F_{(2,30)} = 16.971$, $p < 0.001$, $\text{partial-}\eta^2 = 0.531$),
150 with faster sprints in RUN ($p = 0.013$, ES: 0.26, *small*) and LIFT ($p < 0.001$, ES: 0.43, *small*) relative to
151 CON. Sprints were also faster in LIFT than RUN ($p = 0.032$, ES: 0.18, *trivial*).

152

153 ****INSERT TABLE 1 HERE****

154

155 Trial influenced JH ($F_{(2,30)} = 3.551$, $p = 0.041$, $\text{partial-}\eta^2 = 0.191$) and cognition ($F_{(2,30)} = 12.419$, p
156 < 0.001 , $\text{partial-}\eta^2 = 0.453$), which are also shown in Table 1. Greater JH ($p = 0.021$, ES: 0.15, *trivial*)
157 and cognitive performance ($p = 0.003$, ES: 0.56, *moderate*) were observed for LIFT compared with
158 CON, whilst cognitive performance in RUN also exceeded that in CON ($p = 0.023$, ES: 0.90, *large*).

159 Neither JH nor cognitive performance differed between RUN and LIFT, and JH remained similar in
160 RUN compared with CON.

161

162 Trial did not influence overall readiness but did influence the 'aggression' subscale ($\chi^2_{(2)} = 9.053$, $p =$
163 0.011). This subscale indicated greater self-reported readiness in LIFT relative to CON ($p = 0.022$, ES:
164 0.95 , *large*). No significant relationships were identified between 1RM deadlift strength and changes in
165 any performance parameter following priming (all $p > 0.05$).

166

167

168 **Discussion**

169 This study examined the influence of general and cricket-specific modes of morning priming on indices
170 of cricket-specific physical performance, cognition, and subjective readiness in professional men's
171 cricketers. Lower-body resistance exercise and cricket-specific repeated sprinting performed in the
172 morning improved afternoon sprinting and cognitive performance relative to a rested control condition.
173 Resistance-based priming also enhanced afternoon CMJ performance, while improving aggression
174 markers of readiness compared with CON and producing faster sprints than RUN. These findings
175 indicate that both lifting- and sprinting-based morning priming exercise can improve indices of cricket-
176 specific athletic performance, while also highlighting the potential for feasible or flexible modes of
177 morning priming exercise to enhance cognitive responses in professional men's cricketers.

178

179 Relative to CON, completing six sets of trap bar deadlifts, ranging from 50% to 85% of 1RM, enhanced
180 JH ($+1.1 \pm 0.4$ cm; $\sim 2.5\%$) and cricket-specific sprint performance (-0.07 ± 0.01 s; $\sim 1.2\%$) when
181 assessed ~ 5.5 h later. Such findings support that morning resistance exercise can improve afternoon
182 performance in explosive activities requiring stretch-shortening cycle contributions.^{8, 16, 17} Whilst the
183 precise mechanisms behind these delayed potentiation effects remain somewhat unclear, it has been
184 proposed that transient hormonal responses to resistance exercise may be partly responsible.^{8, 16, 17} In
185 support, benefits to afternoon sprint performance have been observed following upper-body resistance
186 exercise in professional rugby union players, despite a lack of movement specificity.¹⁷ This upper-body
187 priming exercise (bench press: five sets of 10 repetitions at 75% 1RM) attenuated diurnal declines in
188 testosterone concentrations that were observed in the control condition, resulting in $\sim 17\%$ greater
189 testosterone concentrations at the onset of afternoon performance.¹⁷ As other research has found similar
190 findings following whole-body resistance exercise,¹⁶ it seems plausible that favourable hormonal
191 responses may at least partly explain the improved physical performance observed in LIFT compared
192 with CON.

193

194 In line with existing research that has reported improvements in sprint times following running-based
195 priming activities,^{16, 17} this study supports the potential for repeated sprinting in the morning to enhance

196 afternoon sprinting performance, as ‘run-two’ times were improved in RUN (-0.04 ± 0.01 s; $\sim 0.7\%$)
197 compared with CON. Practitioners working in high-performance sport have expressed a reluctance to
198 prescribe high-intensity resistance exercise on the day of competition, noting that this strategy may not
199 fit within a typical training schedule.¹⁹ Moreover, professional cricketers often play matches that require
200 long-distance travel and/or use hotel accommodation before a match. A lack of facilities may thus make
201 heavy resistance exercise difficult to implement.¹⁹ The results of the current study suggest that given
202 the likely presence of substantial barriers preventing competition-day resistance exercise, morning
203 sprinting may offer a more feasible alternative to elicit a performance priming response in professional
204 cricket.

205

206 The efficacy of repeated sprinting as a priming stimulus notwithstanding, afternoon sprints were faster
207 (-0.03 ± 0.01 s; $\sim 0.5\%$) in LIFT compared with RUN. Similar findings have been reported in
208 professional rugby players, for whom morning resistance exercise also offset diurnal declines in
209 testosterone concentrations.¹⁶ Whilst hormonal responses were not assessed in the current study, these
210 observations appear to indicate that high-load (reaching $\geq 85\%$ 1RM) resistance exercise-based priming
211 may produce more favourable explosive physical performance responses relative to morning running
212 interventions. Conversely, Russell et al.¹⁷ reported that afternoon testosterone concentrations were
213 preserved more effectively by morning repeated sprinting than by morning resistance exercise. These
214 hormonal responses were reflected in the fact that running-based priming improved a broader range of
215 physical performance measures (i.e., improved sprinting and CMJ performance following running,
216 versus improved sprinting performance alone following weights). Although the reasons for such
217 discrepancies remain unclear, it is possible that between-study differences in priming stimuli may be
218 somewhat responsible. Indeed, whereas the resistance exercise stimulus implemented by Russell et al.¹⁷
219 consisted of upper-body exercise at $\sim 75\%$ 1RM, the current investigation, plus other research showing
220 favourable priming effects following morning weight training compared with morning running,
221 incorporated lower-body resistance exercises that were performed at higher intensities (i.e., $\geq 85\%$
222 1RM).¹⁶ Collectively, these findings may suggest the importance of choosing priming movements that

223 achieve a sufficient intensity and/or biomechanical or potentially muscle group specificity when seeking
224 to maximise the ergogenic benefits of morning resistance exercise.⁸

225

226 It seems likely that movement intensity may also be relevant with regard to running-based priming
227 exercise. The superior outcomes observed by Russell et al.¹⁷ following running-based priming (i.e.,
228 compared with upper-body resistance exercise) could also be partly attributable to the changes of
229 direction that were incorporated within the repeated sprint protocol. Adding turns increases the intensity
230 of submaximal shuttle running,²⁷ thus this inclusion may have produced greater performance priming
231 effects than did the straight line running protocol implemented by Cook et al.¹⁶ That said, incorporating
232 a 180° turn into each morning sprint in the current study produced less substantial afternoon
233 performance benefits when compared with a high-intensity lower-body resistance exercise session.

234

235 Whereas previous evidence in professional rugby players has suggested no improvement in reaction
236 times following morning priming exercise,¹⁷ both RUN (-2.52 ± 0.82 s; $\sim 4.9\%$) and LIFT (-3.83 ± 0.95
237 s; $\sim 7.4\%$) enhanced afternoon cognitive performance in the present study. Although more research is
238 required to elucidate cognitive responses following morning exercise, some evidence has suggested a
239 positive association between testosterone concentrations and aspects of cognitive ability.²⁸
240 Acknowledging the lack of physiological or hormonal measurements in the current study, it is possible
241 that elevations in testosterone concentrations following morning exercise at least partially explain the
242 benefits observed. Irrespective of the prominent mechanism(s), the potential to enhance afternoon
243 cognitive function through morning priming exercise may be particularly valuable in relation to
244 cricketers, for whom concentration, reaction speed, and anticipation are crucial aspects of match-play
245 performance.^{4,5}

246

247 Practitioners may harbour concerns about the potential for morning priming exercise to elicit additional
248 physical and mental fatigue and/or decrease perceived 'readiness' to perform.¹⁹ It is therefore notable
249 that neither priming intervention decreased players' subjective readiness, while LIFT improved
250 readiness responses on the 'aggression' subscale. Alongside aggression responses potentially

251 suggesting favourable testosterone responses in LIFT,⁹ these observations confirm that the volume and
252 intensity of morning priming exercise in this study was appropriate to improve physical and cognitive
253 performance while maintaining or even improving a player's feelings of readiness amongst this sample
254 of professional cricketers. Such findings may be particularly important given the well-established
255 positive relationship between self-confidence and successful sporting performance.²⁹

256

257 Although this study observed potentially important performance benefits following morning priming
258 exercise in men's professional cricketers, the specific causative factor(s) could not be determined.
259 Morning priming exercise has previously demonstrated efficacy in offsetting the circadian declines in
260 testosterone concentrations that are typically observed throughout the day,^{16,17} with positive correlations
261 having been identified between endogenous testosterone concentrations and indices of physical and
262 potentially cognitive performance.⁹⁻¹¹ However, muscle and deep-body temperature also demonstrate
263 diurnal variations throughout the day while themselves correlating with indices of physical
264 performance.^{24,30} Temperature or other physiological responses (e.g., oxygen consumption, heart rate,
265 ventilation) may have contributed to the beneficial priming effects observed in LIFT and RUN.
266 Notwithstanding, this study provides valuable data to indicate physical and cognitive performance
267 benefits following cricket-specific sprinting or general lower-body resistance exercise priming for tasks
268 commenced ~5.5 h thereafter. Future research investigating the impact of various practically
269 implementable forms of morning priming (including cricket-specific movements such as bowling) on a
270 range of other cricket-specific performance indicators (fast bowling ability, throwing, catching, etc)
271 may add further valuable information.

272

273 **Conclusion**

274 Morning priming exercise consisting of cricket-specific repeated sprint running or lower-body
275 resistance exercise can improve indices of afternoon physical and cognitive performance when
276 commenced ~5.5 h after the priming stimulus. Although the greatest improvements were observed in
277 LIFT, RUN produced superior responses to CON and may represent a viable when morning resistance
278 exercise is not feasible. Such findings allow practitioners to make informed decisions regarding match-

279 day preparatory strategies. Moreover, logistical factors such as travel often make it difficult to schedule
280 resistance training during professional cricketer season. This study may suggest that match-day could
281 represent an opportunity to undertake low-volume resistance exercise in situations where it would be
282 feasible.

283

284 **Practical implications**

- 285 • Morning lower-body resistance exercise reaching ~85% 1RM represents an effective match-
286 day strategy to improve physical and cognitive performance in professional men's cricketers.
- 287 • Simulated running between the wickets offers a viable alternative priming stimulus if
288 circumstances preclude competition-day resistance exercise.
- 289 • The volume and intensity of priming exercises did not reduce perceived readiness.
- 290 • Coaches and players should note the potential influence of general and specific morning
291 activities on afternoon performance, including avoiding excessive exercise volumes which may
292 elicit additional fatigue.

293

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Table 1. Differences in countermovement jump height, sprint time, and Stroop test completion time between the three conditions.

	Jump height (cm)	Sprint time (s)	Stroop test time (s)
CON	44.6 ± 7.0 ^c	5.97 ± 0.16 ^{b, cc}	51.53 ± 5.12 ^{b, c}
RUN	45.2 ± 7.2	5.93 ± 0.15 ^{a, c}	49.02 ± 3.34 ^a
LIFT	45.7 ± 6.9 ^a	5.89 ± 0.15 ^{aa, b}	47.71 ± 2.82 ^a

CON: Control condition, LIFT: Resistance exercise priming condition, RUN: Repeated sprinting priming condition. Data are presented as mean ± standard deviation. a: Significantly different from CON, b: significantly different from RUN, c: significantly different from LIFT. A single letter indicates differences at the p <0.05 level, whilst two of the same letter represents differences at the p <0.001 level).