

1 **Title:** An analysis of variability in power output during indoor and outdoor cycling time-trials

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3 **Submission type:** Original Investigation

4

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29 **Running Head:**

30 Indoor v.s. outdoor cycling performance

31

32

33

34 **Abstract**

35

36 **Purpose:**

37 Regulation of power output during cycling encompasses the integration of internal and external  
38 demands to maximise performance. However, relatively little is known about variation in power output  
39 in response to the external demands of outdoor cycling. We compared mean power output and the  
40 magnitude of power output variability and structure during a 20-min time-trial performed indoors and  
41 outdoors.

42 **Methods:**

43 Twenty male competitive cyclists ( $\dot{V}O_{2peak}$   $60.4 \pm 7.1$  mL·kg<sup>-1</sup>·min<sup>-1</sup>) performed two randomised  
44 maximal 20-min time-trial tests i) outdoors at a cycle-specific racing circuit or ii) indoors on a  
45 laboratory-based electromagnetically braked training ergometer, 7 days apart. Power output was  
46 sampled at 1 Hz and collected on the same bike equipped with a portable power meter in both tests.

47 **Results:**

48 Twenty-min time-trial performance indoor ( $280 \pm 44$  W) was not different from outdoor ( $284 \pm 41$  W)  
49 ( $P = 0.256$ ), showing a strong correlation ( $r = 0.94$ ;  $P < 0.001$ ). Within-person SD was greater outdoors  
50 ( $69 \pm 21$  W) compared to indoors ( $33 \pm 10$  W) ( $P < 0.001$ ). Increased variability was observed across  
51 all frequencies in data from outdoor cycling compared to indoors ( $P < 0.001$ ) except for the very slowest  
52 frequency bin ( $<0.0033$  Hz,  $P = 0.930$ ).

53 **Conclusions:**

54 Our findings indicate a greater magnitude of variability in power output during cycling outdoors. This  
55 suggests that constraints imposed by the external environment lead to moderate and high frequency  
56 fluctuations in power output. Therefore, indoor testing protocols should be designed to reflect the  
57 external demands of cycling outdoors.

58

59 **Key words:** Frequency, Fluctuations, Pacing, Performance, Structure

60 **Introduction:**

61 Pacing refers to an athlete's distribution of work or energy across an event (de Koning et al. 1999;  
62 Abbiss and Laursen 2008). Athletes vary their physical output (i.e. mechanical power output) to  
63 accommodate physiological or psychological constraints, for strategic racing purposes, or due to  
64 changing environmental factors (St Clair Gibson et al. 2006; Abbiss and Laursen 2008).  
65 Accommodation of these varying internal and external demands directly affect performance (Foster et  
66 al. 1994) with the adopted pacing strategy representing a behavioural expression of continuous decision  
67 making (Smits et al. 2014). When examined at increased resolution, these fluctuations may illustrate  
68 complex intrinsic control strategies to modulate work rate (Tucker et al. 2006) and reflect multiple  
69 levels of regulation to achieve homeostatic control during a task (Lambert et al. 2005; St Clair Gibson  
70 et al. 2006; St Clair Gibson et al. 2018). Given the additional external demands associated with  
71 performance cycling outdoors, it is interesting that mean power data is comparable indoors and outdoors  
72 over shorter duration 6-s sprints (Gardner et al. 2007), 4-min time-trials (Bouillod et al. 2017) and  
73 longer duration 40-km time-trials despite a ~ 6% reduction in performance time outdoors (Smith et al.  
74 2001).

75

76 Relatively little is known about variation in power output in response to more immediate external  
77 demands of pacing during outdoor cycling such as, short strategic sprints, reductions in speed to  
78 facilitate manoeuvring and/or changes in gradient, or attentional fluctuations whilst scanning for  
79 potential hazards. Outdoor cycling performance time can be optimized by adopting a strategy that varies  
80 power output by 5-10% (Swain, 1997), increasing power during uphill or windy sections and reducing  
81 during downhill or less-windy sections (Swain 1997; Atkinson and Brunskill 2000; Abbiss and Laursen  
82 2008). However, the less predictable attentional demands of the outdoor environment which remain in  
83 constant flux and require continual updates, conscious or otherwise, may also impact performance (St  
84 Clair Gibson et al. 2018). Variation in power output has been described in professional level time-trials  
85 conducted outdoors (Abbiss et al. 2010), and low frequency fluctuations in power output have been  
86 observed during indoor flat and simulated hilly conditions (Terblanche et al. 1999; Tucker et al. 2006).

87 However, the magnitude of power variability between different environmental conditions and the  
88 differences in physiological and mechanical demands and associated effects on cycling performance  
89 have not been well described.

90

91 Comparison of time-series mechanical power data at increased resolution can offer further insight into  
92 the effects of environmental constraints on centrally controlled regulation of exercise intensity and  
93 subsequent behavioural outcomes, to different environments. We hypothesized that cycling in the  
94 outdoor environment might change (at some organisational level) the pattern of the oscillations in power  
95 output across time (St Clair Gibson et al. 2018). This may, in turn, allow athletes to better understand  
96 the necessity of environmental specificity when translating indoor performance to the outdoors.  
97 Therefore, the aims of this study were to i) compare the mean power output across a 20-min cycling  
98 time-trial conducted indoors and outdoors, ii) compare the magnitude of variability across different  
99 frequency bandwidths, iii) and establish whether fluctuations of power output are structured or due to  
100 random noise.

101

102 **Methods**

103

104 *Participants*

105 Twenty male cyclists (mean  $\pm$  SD; age  $36 \pm 9$  years, stature  $180 \pm 5$  cm; body mass  $76 \pm 8$  kg;  $\dot{V}O_{2\text{peak}}$   
106  $60.4 \pm 7.1$  mL $\cdot$ kg $^{-1}$  $\cdot$ min $^{-1}$ ) volunteered to participate in this study. Cyclist's performance level (PL) was  
107 categorised based on their relative  $\dot{V}O_{2\text{peak}}$  according to de Pauw et al. (2013): 6 = PL2; 6 = PL3; 6 =  
108 PL4; 2 = PL5. All cyclists were active in regional/national racing time trials, road races or triathlons  
109 and were familiar with time-trial performance tests. Written informed consent was obtained from each  
110 participant before testing. All procedures conformed to standards set by the *Declaration of Helsinki* and  
111 ethical approval was granted by the institutional ethics committee.

112

113 *Study design*

114 Participants completed three separate testing sessions, which included two randomised 20-min time-  
115 trial tests with data collected consistently using the same portable power meter either i) outdoors at a  
116 cycle-specific racing circuit (Figure 1) or, ii) indoors on a laboratory-based electromagnetically braked  
117 training ergometer, 7 days apart. The third visit was an incremental ramp test to exhaustion for the  
118 purpose of establishing maximal aerobic capacity. The participants were asked to refrain from strenuous  
119 exercise for 48-h before each test, as well as alcohol and caffeine 24-h before testing, and to arrive fully  
120 hydrated.

121

122 *Indoor vs. outdoor tests*

123 All performance tests on the same bicycle (Dolan Preffisio, size 56, Dolan Bikes, Ormskirk, UK) fitted  
124 with a portable left crank-based power meter (STAGES, Stages Cycling, Boulder, CO, USA) and data  
125 collected via a Garmin head unit (Garmin Edge 510 GPS headunit, Garmin (Europe) Ltd., Southampton,  
126 UK). Participants completed a self-selected warm up at  $\sim 100$  W for 10-min which included 2 x 20-s  
127 maximal efforts before resting for 5-min. Indoor tests were performed on an electronically-braked  
128 indoor trainer (Computrainer, RacerMate One, Racermate, Seattle, USA). Prior to each trial, the

129 recommended zero off-set calibration was performed for the STAGES power meter according to the  
130 manufacturer's instructions. For indoor tests the Computrainer was calibrated according to the  
131 manufacturer's instructions and a tyre roll-down test performed to maintain a standardized rolling  
132 resistance (~ 3.0 lbs) across all testing, tyre pressure was controlled at 100 pounds per square inch [psi].  
133 A commercially available plastic riser was placed under the front wheel to level the bicycle and gradient  
134 set at 0%. Ambient temperature was controlled to approximate outdoor air temperatures (Table 1). Fan  
135 cooling was provided during indoor tests to approximate conductive air movements experienced  
136 outdoors and was positioned in front of the cyclist at an angle of 45 degrees and set to an air speed of  
137 10.4 km/h (HVD24, Sealey Power Products, Bury St Edmunds, UK). It did not rain on any outdoor test  
138 day. Outdoor tests were conducted on a cycle-specific, traffic-free race circuit. The track measured 1.52  
139 km in distance, 6 m wide, with ~ 4 m total elevation gain per lap and 7 shallow corners that allowed  
140 continuous pedalling (Figure 1). In total, participants completed between 7-10 laps. During both tests,  
141 participants were allowed to change gear to increase resistance during the test and cadence was freely  
142 chosen dependant on their preferred pacing strategy. Participants were instructed to pace their efforts  
143 to achieve the highest average power output across the 20-min effort. Blood samples were collected 1-  
144 min pre and 1-min post-test from the earlobe via capillary puncture and analysed subsequently using an  
145 automated blood lactate analyzer (Biosen C-Line, EKF Diagnostics, Cardiff, UK). Heart rate was  
146 recorded continuously throughout all trials by a Garmin heart rate monitor (HRM3-SS, Garmin  
147 (Europe) Ltd., Southampton, UK) that wirelessly transmitted to the Garmin headunit. Participants were  
148 also asked to rate their perceived levels of exertion using the RPE scale at the end of the 20-min test.  
149 Non-specific verbal encouragement was given each lap (~ 2-3-min intervals) and was approximately  
150 time-matched for indoor trials. Power output and heart rate data were recorded but concealed from the  
151 participant. During the test, a countdown clock from 20-min on a Garmin headunit attached to the  
152 handlebars of the bike was the only visible external cue.

153

#### 154 *Incremental ramp test*

155 The incremental ramp test was programmed by the indoor cycle trainer software, starting at 150 W and  
156 increasing by 1 watt every 2-s ( $30 \text{ W}\cdot\text{min}^{-1}$ ), until volitional exhaustion. Breath-by-breath gas

157 exchanges were recorded to assess oxygen consumption ( $\dot{V}O_2$ ) (Oxycon Pro, Erich Jaeger GmbH,  
158 Hoechberg, Germany).

159

#### 160 *Data processing*

161 Power output data was sampled at 1 Hz and variability examined in several ways. First, the distribution  
162 of power output for both conditions was calculated by creating a histogram ranging from 0-750 W in  
163 10 W bins for each person. The proportion of 1 s samples in each 10 W bin of the histogram was  
164 calculated for each participant and then averaged (mean) over the cohort. Next, the within-person  
165 standard deviation of power output was calculated for both conditions. Third, to better understand the  
166 variability of power output at different frequencies, we i) tested the within-person standard deviation  
167 for data filtered (4<sup>th</sup> order Butterworth filter) from very slow frequencies (below 0.0033 Hz, 1 cycle  
168 each 300 s) to higher frequencies (0.5 Hz, 1 cycle each 2 s), in bins of 0.033Hz; and ii) visualised the  
169 frequency domain using Fast Fourier Transform which was extracted for each participant and then  
170 averaged (mean) over the cohort. Finally, detrended fluctuation analysis (DFA) was applied to the time  
171 series to better understand the underlying structure of the variability. We interpreted an  $\alpha = .05$  resulting  
172 from the DFA analysis as random noise. In contrast, values of  $0 < \alpha < 0.5$  and  $.05 < \alpha < 1.0$  both  
173 indicates persistent long-range correlations in the fluctuation of power output (Peng et al. 1995).

174

#### 175 *Statistical Analysis*

176 A Paired Student's *t*-test was used to examine paired data for performance between conditions. A two-  
177 way analysis of variance (ANOVA) for repeated measures was used to test for within-group effects  
178 across time and condition (indoors vs. outdoors). If sphericity was violated, a Greenhouse-Geisser  
179 correction was applied. When a significant difference was found for a main effect (condition or time),  
180 *post-hoc* pair-wise comparisons were made, incorporating a Holm Bonferroni adjustment. All statistical  
181 analyses were performed using SPSS (IBM SPSS statistics 22 Inc, USA). Data are presented as mean  
182  $\pm$  SD ( $n = 20$ ). Significance was set at  $P < 0.05$ .

183 **Results**

184

185 ***Time trial performance indoor vs. outdoor***

186 Mean 20-min power output during a time-trial conducted indoors ( $280 \pm 44$  W) was not different from  
187 outdoors ( $284 \pm 41$  W) ( $t_{(19)} = 1.170$ ;  $P = 0.256$ ), showing strong correlation ( $r = 0.94$ ;  $P < 0.001$ ) with  
188 a typical error of  $\pm 10$  W (Figure 2A). Cycling cadence was higher indoors compared to outdoors (In:  
189  $97 \pm 8$ , Out:  $90 \pm 7$  rev·min<sup>-1</sup>) ( $t_{(19)} = -3.749$ ;  $P = 0.001$ ). Physiological measures of average heart rate  
190 (In:  $172 \pm 12$ , Out:  $171 \pm 10$  beats·min<sup>-1</sup>) ( $t_{(19)} = -0.810$ ;  $P = 0.428$ ) and end test lactate [La] (In:  $9.9 \pm$   
191  $2.7$ , Out:  $10.3 \pm 2.7$  mmol·L<sup>-1</sup>) ( $t_{(19)} = -0.394$ ;  $P = 0.698$ ) were not different. RPE was lower outdoors  
192 compared to indoors (In:  $19.4 \pm 0.9$ , Out:  $18.2 \pm 0.8$ ) ( $t_{(19)} = -6.902$ ;  $P > 0.05$ ).

193

194 ***Variability in power output***

195 The within-person standard deviation of power output was greater when cycling outdoors (mean:  $69 \pm$   
196  $21$  W) compared to indoors (mean:  $33 \pm 10$  W) ( $t_{(19)} = 7.239$ ,  $P < 0.001$ ), with no correlation ( $r = 0.13$ ;  
197  $P = 0.594$ ) (Figure 2B). Histograms averaged across participants show that the increased variability of  
198 power output during outdoor cycling was due to a greater proportion of both lower and higher power  
199 outputs (Figure 3A). Increased variability in power output was observed across all frequencies in data  
200 from outdoor cycling compared to indoors, with main effects for frequency ( $F_{(48,912)} = 134.548$ ,  $P <$   
201  $0.001$ ) and cycling location ( $F_{(1,19)} = 75.633$ ,  $P < 0.001$ ), and interaction ( $F_{(48,912)} = 26.937$ ,  $P < 0.001$ )  
202 (Figure 3B). *Post hoc* analysis revealed that variability was higher across all frequencies during outdoor  
203 cycling except for the very slowest frequency bin ( $<0.0033$  Hz, 1 cycle per 300 s), where there was no  
204 difference between the two conditions ( $P = 0.930$ ). Distinct peaks occurred at frequencies slower  
205 than  $0.0033$  Hz ( $>300$  s per cycle), with two additional peaks for outdoor cycling at  $\sim 0.01$  Hz (100 s  
206 per cycle) and  $\sim 0.08$  Hz (12.5 s per cycle)(Figure 3C). To illustrate variability of power output across  
207 different frequencies, a low pass filter ( $<0.0055$ Hz,  $> 180$  s per cycle), band pass filter (0.0055-.2 Hz,  
208 5-180 s per cycle) and high pass filter ( $>0.2$  Hz,  $< 5$  s per cycle) was applied to a representative data set  
209 for one participant (Figure 4). An increase in variation of power output is evident in the unfiltered data,  
210 indicative of the increased within-person standard deviation (Figure 4A). The low pass filtered data



211 shows slow variations in power output across the trial (Figure 4B). In contrast, the bandpass filter (5 –  
212 180 s per cycle) reveals large variations of power output during the outdoor trial (Figure 4C) and the  
213 high pass filtered data illustrates greater variability (quicker than 0.2 Hz) in power output over the entire  
214 outdoor trial (Figure 4D).

215

#### 216 ***Structure of power output fluctuations***

217 Detrended fluctuation analysis resulted in an  $\alpha$  of between  $0.5 < \alpha < 1$ , indicating an underlying structure  
218 in the fluctuations of power output rather than random noise for both indoor (mean:  $0.85 \pm 0.22$ ) and  
219 outdoor conditions (mean:  $0.85 \pm 0.12$ )( $P = 0.894$ ).

220

## 221 **Discussion**

222

223 We examined how power output varied across different frequencies when trained cyclists performed a  
224 20-min cycling time-trial under laboratory-based indoor and field-based outdoor conditions. Mean  
225 power output was not different between conditions but there was greater variability in power output  
226 outdoors. Analysis of different frequency bandwidths revealed the presence of slow oscillations in  
227 power output both indoors and outdoors, suggestive of an underlying global physiological control  
228 strategy. Greater variability in power output during cycling outdoors beyond these slow oscillations  
229 appeared to reflect the cyclical nature of the outdoor circuit. However, increased variability in power  
230 output at higher frequencies when cycling outdoors suggest that modifications in mechanical work rate  
231 occur that are not replicated during an indoor task.

232

233 There was no difference in mean power output (~ 1% difference) between 20-min time-trials performed  
234 on an outdoor cycling circuit or an indoor electronically-braked trainer. Indeed, outdoor and indoor  
235 measures were strongly correlated. These findings are in agreement with previous studies that have  
236 reported comparable mean power output for shorter 4-min time-trials (~3% difference) (Bouillod et al.  
237 2017) and longer 40 km time trials (~3% difference) (Smith et al. 2001) (> 1% difference) (Jobson et  
238 al. 2008), performed indoors and outdoors. However, despite the relative consistencies in power output,  
239 a notable increase in the variability of power output during cycling performed outdoors was only  
240 recognizable with an increased level of resolution. Within-person standard deviation was increased  
241 more than two-fold outdoors ( $69 \pm 21$  W) relative to indoors ( $33 \pm 10$  W). The lack of correlation and  
242 spread of standard deviations across the outdoor condition (Figure 2B) suggest that no relationship  
243 exists with the variability observed during an indoor performance test. Therefore, from a practical  
244 perspective, coaches and athletes should be aware that some individuals might adopt greater variation  
245 in their pedaling when outdoors, which would not be evident during indoor testing. In general, greater  
246 variability in outdoor cycling was achieved via a greater spread in power intensities utilised during  
247 cycling outdoors. To further describe the variability in power output, we examined the within-person

248 standard deviation across low, moderate and high frequency bands. We observed that power output was  
249 more variable across all frequencies outdoors relative to indoors, except for very slow frequencies.

250

251 Slow variations ( $< 5$  cycles per min,  $0.003$  Hz) in power output were consistent to both indoor and  
252 outdoor performance tasks, possibly indicative of a change in pacing strategy. Such slow variations  
253 have been previously demonstrated where an equivalent dominant frequency band was described for  $\sim$   
254  $2.5$  km cycles during a  $20$  km indoor performance time trial (Tucker et al. 2006). These oscillations  
255 were also evident during indoor cycling using a modified cycle ergometer that was able to simulate a  
256 hilly route (Terblanche et al. 1999). Similar to the current study, these slow fluctuations described by  
257 Terblanche et al. were independent of the nature of the course profile. Such control mechanisms have  
258 been proposed to reflect self-regulation whereby intrinsic biological control processes within the central  
259 nervous system respond to changing afferent information from the exercising muscles (St Clair Gibson  
260 et al. 2006; Tucker et al. 2006). Similar global fluctuations have also been reported across a range of  
261 other biological systems, such as in heartbeat dynamics (Ivanov et al. 1999) and during changes in gait  
262 stride during walking (Hausdorff 2005).

263

264 Notable peaks in variability at  $\sim 100$  s per cycle ( $0.013$  Hz) and  $20$  s per cycle ( $0.093$  Hz) were identified  
265 for the outdoor condition only. The fluctuations of power output in this frequency band are indicative  
266 of the cyclical nature of the outdoor  $1.52$  km circuit. A representative dataset illustrates the temporal  
267 nature of the time-trial outdoors with data filtered over the range  $\sim 5$ - $180$  s (Figure 4C). Variation in  
268 power output as a result of changes in elevation would prompt a greater application of power (Swain  
269 1997), whereas corners in the cycle circuit would encourage a reduction in power, possibly explaining  
270 these observed micro-adjustments. These apparent pacing strategies, adopted consciously or  
271 subconsciously, support our understanding that modulating effort is important to distribute pace/power  
272 output effectively across the test duration over variable terrain (Swain 1997; Atkinson and Brunskill  
273 2000; Abbiss and Laursen 2008). Atmospheric conditions such as wind direction that favored different  
274 parts of the circuit likely contributed as well. Regardless of the differences in pacing adopted by the  
275 athletes both approaches were equivalent in achieving a comparable maximal mean power output in

276 their respective environments. However, when examining this variation outdoors at higher frequencies  
277 the differing mechanical demands evident in the application of power output suggest that these  
278 performances are not equivalent.

279

280 Greater variability in power output was observed at higher frequencies ( $< 5$  s per cycle, 0.2 Hz) when  
281 riding outdoors (Figure 3D). These stochastic modifications in external force over brief periods did not  
282 however reflect changes in the circuit (Figure 4D). These high-frequency adjustments appear to be  
283 driven by environmental constraints such as variations in road surface, micro-environmental changes  
284 in air movement, or may reflect the increased cognitive demand associated with attending to balance  
285 via steering control inputs and rider lean (Cain et al. 2016). Muscle coordination has been shown to be  
286 dependent on the distribution of power and terrain profile in outdoor cycling (Blake and Wakeling  
287 2012), suggesting that neuromuscular demands may be altered. Whereas, psychological stressors  
288 associated with attentional scanning strategies for planning and safety may also have impacted the  
289 intrinsic feedforward complexity in the regulation of power. Indeed, the visual exploration of  
290 environmental challenges in a relatively more unpredictable setting outdoors may have increased the  
291 attentional effort, something that would be reduced during an indoor task (Lacaille et al. 2004). In  
292 contrast, reallocation of attention towards novel stimuli outdoors, whilst increasing the cognitive  
293 demand, has been shown to reduce the sensation of effort during repetitive tasks, such as cycling  
294 (Bigliassi et al. 2017), which is supported by a reduction in RPE noted in our study outdoors. The  
295 relation between the cognitive demands of cycling and central control strategies warrants further  
296 investigation. Interestingly, measures of heart rate (HR) and indices of muscle bioenergetics (end-test  
297 B[La]) were similar across both indoor and outdoor tests suggesting that despite larger variability in  
298 power output this did not appear to increase the metabolic demands of exercise performance. This was  
299 unexpected; however, further research should interrogate time-series changes in heart rate and  
300 neuromuscular control during indoor and outdoor cycling, to explore the physiological significance of  
301 such variation in mechanical power.

302

303 Detrended fluctuation analysis indicated that the subtle changes in power output across both indoor and  
304 outdoor trials were not due to random noise. Rather, we found evidence of underlying self-similar  
305 patterns across different timescales, consistent with previous studies (Tucker et al. 2006). The findings  
306 were similar for both indoor and outdoor conditions, indicating that these patterns likely correspond to  
307 more global neuromuscular, physiological and psychological control mechanisms independent of the  
308 environment. Higher resolution testing using direct neuromuscular and physiological testing is required  
309 to better explain the nature of these patterns and underlying causes.

310

### 311 *Practical applications*

312 Our findings shed light on the characteristics of power output variation in two different environments.  
313 To prepare specifically for most cycling competitions, indoor testing protocols should reflect the  
314 external demands of cycling outdoors. An understanding of the design of indoor exercise protocols,  
315 which elicit equivalent mechanical responses, may drive adaptations that are more specific. However,  
316 careful consideration is needed to accurately simulate the variation in power output observed among  
317 competitive cyclists during outdoor training. This could be achieved by simulating (via ergometry  
318 control) realistic changes in power output to reflect varying demands, such as terrain and environment,  
319 or by designing interventions to increase cognitive engagement or distraction during the test. However,  
320 it is currently unclear how best to replicate these subtle, intrinsic variations in power. Future research  
321 should investigate ways to achieve this.

322

### 323 *Conclusion*

324 Our study demonstrates that measures of mean power output are similar during performance tests when  
325 cycling indoors and outdoors. However, outdoor cycling leads to moderate and high frequency  
326 variations in power output. This variation of power output in different frequency bands may reflect an  
327 altered neuromuscular demand during cycling time-trials conducted outdoors. Therefore, our findings  
328 should be considered when seeking to replicate the demands of outdoor competition using indoor  
329 training methods.

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391

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393

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395

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398 endorsement of the product by the authors or the journal.



399 Table 1. Ambient conditions for performance tests performed indoors and outdoors.

400

	<b>Indoor time-trial</b>	<b>Outdoor time-trial</b>
Temperature (°C)	17 ± 1	11 ± 3
Humidity (%)	33 ± 8	54 ± 15
Barometric Pressure (hPA)	1014 ± 15	1016 ± 9
Wind speed (km.h <sup>-1</sup> )		13.4 ± 5
Fan speed (km.h <sup>-1</sup> )	10.4 ± 0	

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404 **Figure legends**

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406 **Figure 1.** Outdoor cycle circuit 1.52 km (A) circuit design (B) elevation profile equating to > 5 m gain  
407 per lap.

408

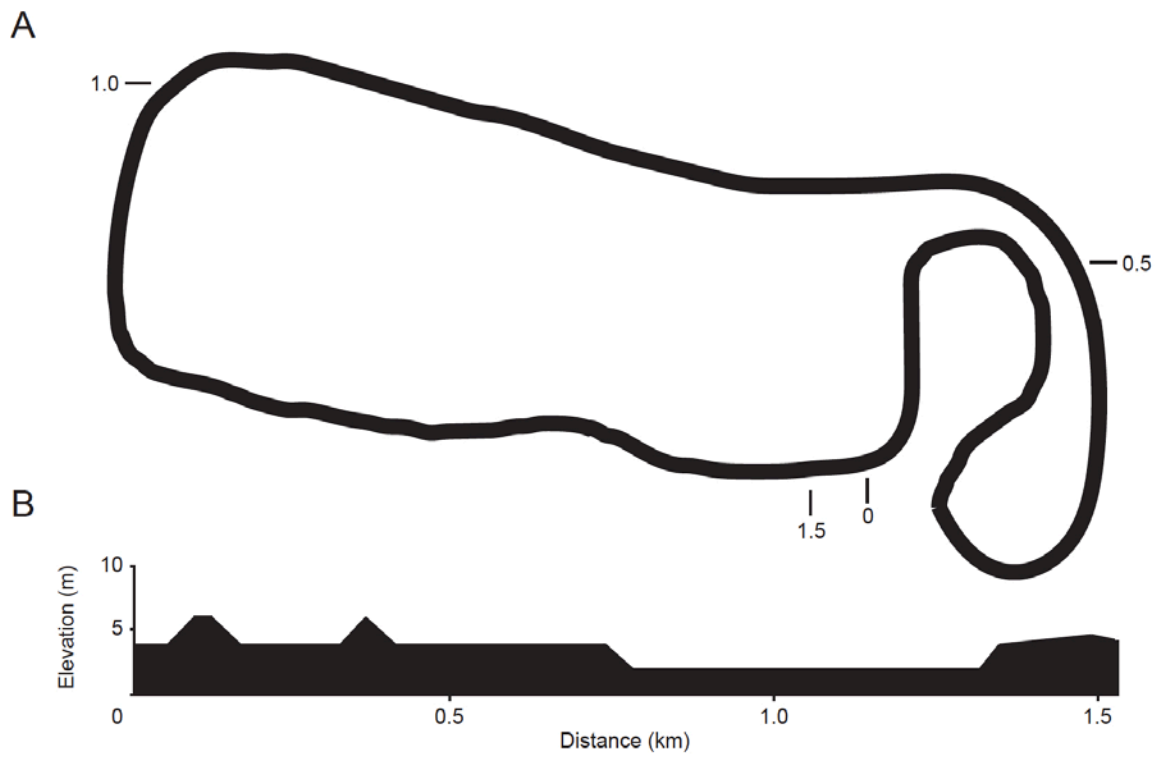
409 **Figure 2.** Scatterplot of (A) mean and (B) standard deviation (SD) of power output during 20 minutes  
410 of outdoor and indoor cycling.

411 **Figure 3.** Power output data recorded during a 20-min time-trial shown for all 20 participants. (A)  
412 frequency histogram of mean power output data; (B) mean within-person standard deviation expressed  
413 as a function of frequency; (C) discrete Fourier transform of the mean power output of all participants.  
414 Indoor cycling represented by a dashed line and outdoor cycling by a solid black line. \*  $P < 0.05$ .

415 **Figure 4.** Representative data filtered ( $n = 1$ ) (A) raw data for outdoor and indoor cycling during a 20-  
416 min time trial (B) low pass filter (> 180 s cycles) (C) moderate pass filter (5-180 s cycles) (D) high pass  
417 filter (< 5s cycles).

418

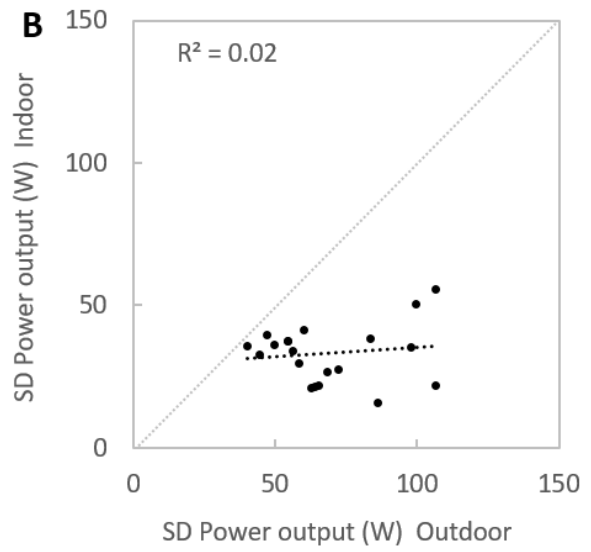
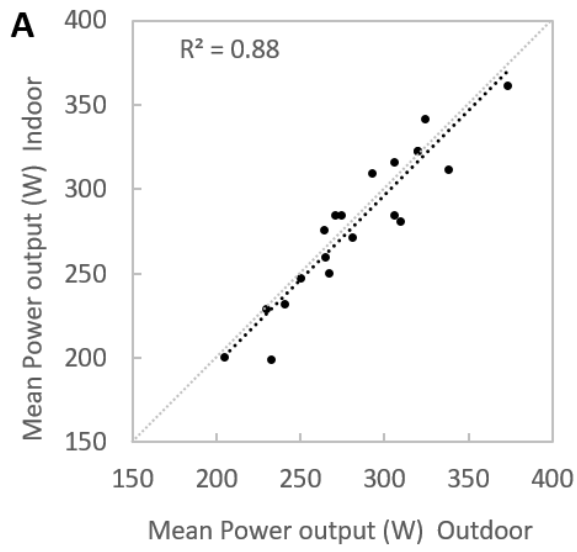
419 Figure 1



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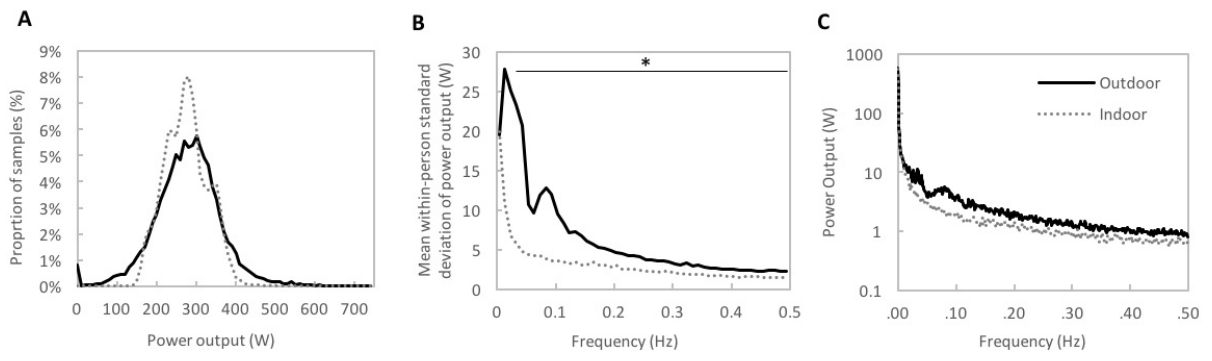
422 Figure 2



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424

425 Figure 3



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