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1 **MANUSCRIPT TITLE: A PERFORMANCE ANALYSIS OF A STAND UP PADDLE**

2 **BOARD MARATHON RACE**

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4 **RUNNING HEAD: A PERFORMANCE ANALYSIS OF SUP**

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18 **ABSTRACT**

19 Stand up paddle boarding (SUP) is a rapidly growing sport and recreational activity in which
20 little scientific research exists. A review of the literature failed to identify a single article
21 pertaining to the physiological demands of SUP competition. The purpose of this study was
22 to conduct a performance analysis of a national level SUP marathon race. Ten elite SUP
23 athletes (6 male, 4 female) were recruited from the Stand Up Paddle Surfing Association of
24 Australia to have their race performance in the Australian Titles analyzed. Performance
25 variables included SUP speed, course taken and heart rate, measured with a 15Hz GPS unit.
26 Results demonstrated that there was a variation in distance covered (13.3km–13.9km), peak
27 speed (18.8km/hr–26.4km/hr) and only moderate correlations ($r=0.38$) of race result to
28 distance covered. Significantly greater amounts of time were spent in 5-10km/hr speed zones
29 ($p<0.05$) during the race. Peak heart rate varied from 168-208bpm amongst the competitors
30 with the average heart rate was 168.6 ± 9.8 bpm. Significantly higher durations were spent in
31 elevated heart rate zones ($p<0.05$) with participants spending 89.3% of their race within 80-
32 100% of their age-predicted HRmax. Marathon SUP races appear to involve a high aerobic
33 demand, with maintenance of near max heart rates required for the duration of the race. There
34 is a high influence of tactical decisions and extrinsic variables to race results. These results
35 provide a greater understanding of the physiological demands of distance events and may
36 assist in the development of specialised training programs for SUP athletes.

37

38 Key words: GPS analysis, water sports, paddle boarding, SUP, Stand Up Paddle.

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42 **INTRODUCTION**

43 Stand up paddle boarding (SUP) is a new sport, the popularity of which has risen
44 exponentially over the past decade (4). A recent report highlighted that participation in SUP
45 in the United States increased 155% from the year 2010 to 2014, with the major reason
46 provided for participation being for exercise and to get fit (17). It is a hybrid of surfing and
47 paddling in which participants can either distance paddle and/or surf waves with competitions
48 being held around the world which culminate in an annual world title event sanctioned by the
49 International Surfing Association (7, 13). Despite this global popularity, there is currently no
50 scientific literature available regarding the performance aspect of SUP.

51

52 The sport involves athletes paddling in a standing position on a board similar to a surfboard
53 however longer (~8-15ft), thicker (4-8in) and wider (26-31in) than traditional surfboards
54 (14). Propulsion of the board is through a long single-bladed paddle in which the athlete
55 alternates sides ad libitum. The general disciplines of competitive SUP include technical
56 racing, surfing and marathon racing. Technical SUP racing consists of a 4-8km sprint in
57 which participants are limited to a maximum board length of 12'6" (3.81m). Surfing events
58 are held in heats of 20 minutes and 30 minute finals in which the top two scoring waves are
59 counted toward the competitors total (15). Scoring is based upon performing manoeuvres,
60 creating power and speed and getting through closing out sections in a similar manner to
61 traditional surfing. The SUP marathon races, normally over a distance of 20km (12.43miles),
62 allows boards up to 14' with a fixed fin and can be conducted in both open ocean and flat
63 water. Longer races however such as one of the most popular open ocean races, the 'Molokai
64 to Oahu' is a crossing of the Ka'iwi channel in Hawaii a distance of 51.5km (32miles). The
65 Ka'iwi channel of 'channel of bones' as it is know is notorious for its large swells of up to 12

66 feet and strong currents (16). It is regarded as the ultimate challenge of physiological
67 endurance and wave riding skills for professional paddlers and water athletes.

68

69 As SUP increases in popularity and competitiveness, the importance of testing SUP athletes
70 to provide information for both coaches and athletes increases in parallel. Although the
71 majority of physiological testing of athletes is performed under highly-controlled laboratory
72 conditions, these are often not sport specific conditions (8, 14). Endurance athletes commonly
73 use heart rate (HR) monitors as a training tool to monitor exercise intensity and recovery,
74 they are also extremely useful to monitor and to plan training (1). Quantifying movement
75 patterns via global positioning systems (GPS) in sport is also important for coaches and
76 athletes to develop sport specific conditioning programs and to prevent training errors (10).

77

78 Research on surfing has identified both internal and external factors which are relevant to
79 surfing performance which may also be applicable to SUP (9). Race results and ultimately
80 race time will depend upon extrinsic variables such as swell (direction and height), currents
81 and wind. Skilled competitors will catch 'bumps' of swell in order to maximise their speed in
82 the open ocean and therefore may choose to alter their line in order to maximise opportunities
83 to catch 'bumps'. Previous research on windsurfing races have shown great variability in total
84 distance covered by competitors (12). It is well known that varying distances can be covered
85 in running marathons when not taking the inside line (point to point strategy) and participants
86 may significantly add additional distance and subsequently extra time to their race. Intrinsic
87 variables can include aerobic and anaerobic fitness of the paddler, balance, stroke rate, length
88 and power output and the racing line chosen by the competitor. As the SUP athlete alternates
89 paddling on each side, the direction of the SUP can be affected while racing and results in

90 non-linear movements as the competitor propels themselves forward. Often the side chosen to
91 paddle on is dictated by the extrinsic variables encountered during the event.

92

93 Along with the effect of intrinsic and extrinsic variables on SUP marathon races, heart rate
94 intensities during SUP competition are unknown therefore limiting competition preparation
95 and training. The primary aim of this study was therefore to determine the cardiovascular
96 demands of a SUP marathon race and the peak and average speeds attainable during a race.
97 The secondary aim was to determine differences in distance covered due to extrinsic
98 variables on the day and their influence on race results. This study aims to inform athlete
99 preparation and to assist coaches in planning conditioning and race tactics.

100

101 **METHODS**

102 *Experimental Approach to the Problem*

103 To determine the cardiovascular demands of an elite marathon race, a performance analysis
104 measuring peak and average heart rate, peak speed and distance covered was conducted with
105 the use of GPS and HR telemetry. Data was categorised into zones for both heart rate and
106 speeds for the duration of the race to highlight the requirements of this form of competition.
107 To ascertain the effect of the extrinsic variables on the day (swell, currents and wind) total
108 distance covered was correlated to race result.

109

110 *Subjects*

111 A total of ten elite (6 male, 4 female) ranked SUP participants (34.78 ± 11.49 yrs) recruited
112 from the Stand Up Paddle Surfers Australia volunteered to participate in this study. SUP
113 participants were competing in the Australian titles in the marathon distance event as a
114 qualifying event for the Australian team for the world championships. The participants were

115 all currently ranked nationally or internationally with all participants being ranked in the
116 national top 10 or international top 24. Each participant was informed of the benefits and
117 risks of the investigation and signed an intuitively approved informed consent document
118 prior to participation in this study. This study was approved by the University Human
119 Research Ethics Committee (RO-1550).

120

121 *Procedures*

122 Each participant was familiarised with the GPS device and instructed where to place both the
123 heart rate strap and GPS receiver unit (GPSports HPISPU, 15Hz, dimensions = 74mm x
124 42mm x 16mm, weight = 67grams). The heart rate straps (T34 transmitter, 5kHz, Polar,
125 Finland) were placed around the participant's chest and the GPS units were placed in a water
126 proof zip-lock bag on the front or back pocket of the participant's hydration packs worn on
127 the chest. The point to point distance of the SUP marathon event was 12.7 km (7.89miles)
128 and the course headed in a southerly direction to an inlet 11.3km (7.02miles) away with a
129 subsequent 1.4km (0.87miles) paddle through a river mouth and into the river in a 'westerly'
130 direction.

131

132 The environmental conditions on the day involved a 0.89m low tide, 11 knot average
133 northerly wind with 14 knot gusts, 0.5m of ENE swell with a 5 sec wave period at the
134 beginning of the race. All GPS units were activated 10 minutes prior to the start of the event
135 to ensure they linked up with the required number of satellites ($n > 3$). Following completion
136 of the event, raw data was downloaded using specialised software (GPSports: Team AMS
137 Release R1) and the pre and post-event periods were eliminated from data analysis.

138

139

140 **Statistical Analyses**

141 Descriptive statistics were used to determine means, ranges and standard deviations of each
142 of the results obtained. A Pearson correlation analysis between distance covered and race
143 result was also performed. Normality was assessed via Shapiro-Wilk ($p < 0.05$). Data which
144 was not normally distributed was assessed using a Friedman Test with a Wilcoxon Signed
145 Ranks test post hoc. All data analysis was conducted using Statistical Package for the Social
146 Sciences (SPSS, version 20.0, Armonk, NY, USA).

147

148 **RESULTS**

149 Nine out of the ten participants finished the race with one participant having to withdraw due
150 to minor injury (muscle strain). Their individual course plots are shown in Figure 1, where at
151 the widest point while in the open ocean, participants were spread 660m apart from one
152 another.



153

154 **Figure 1: GPS plot of individual courses taken during the race.**

155 As seen in Table 1, athletes spent 89.31% of their race within 80-100% of their age predicted
 156 HRmax (220-age) and spent a significantly higher ($\chi^2(4) = 25.36, p < 0.001$) amount of time
 157 in zone 3 (80-90% of HRmax) and zone 4 (90-100% of HR max) than the other zones. There
 158 was a significant difference in duration spent in speed zones ($\chi^2(4) = 33.69, p < 0.001$) with
 159 significantly more time spent in the 5-10km/hr zone ($Z = -2.666, p = 0.011$). Incremental
 160 increases in cardiovascular demand as seen by elevation of heart rate were seen from the start
 161 of the race with maintenance of 80-100% of the participants HRmax for the duration of the
 162 race. Speed is seen to be more variable with peak speed being at the point when participants
 163 were paddling in a westerly direction, enabling them to ride waves.

164

165 **Table 1: Time spent in velocity and heart rate zones for the race. Values presented are mean \pm SD.**

	Velocity (km/hr)	Time (s)	Time (%)	% HR Max	% of race
Zone 1	0-5	46.48 \pm 36.58 \times^*	0.90 \pm 0.59%	60-70%	4.84 \pm 7.60% *†
Zone 2	5-10	3353.83 \pm 958.36 *	66.06 \pm 13.03%	70-80%	3.95 \pm 4.38% *†
Zone 3	10-15	1567.12 \pm 527.09 \times	32.30 \pm 12.89%	80-90%	27.46 \pm 34.02%
Zone 4	15-20	34.03 \pm 21.94 \times^*	0.71 \pm 0.50%	90-100%	61.85 \pm 32.12%
Zone 5	>20	1.38 \pm 1.89 *††	0.03 \pm 0.04%	>100%	1.09 \pm 4.50% *†
	Total	5002.95 \pm 447.86	100%	Total	100%

166 + = significantly less than zone 1, \times = significantly less than zone 2, * = significantly less than zone 3

167 $p < 0.05$, \dagger = significantly less than zone 4 $p < 0.05$)

168

169 The group, male and female averages displayed in Table 2 shows that participants covered an
 170 average distance of 13.56km with a range of 13.34km to 13.87km. Time to completion varied
 171 from 1:15.1 to 1:39.9. Peak heart rate recorded ranged from 168bpm (98%HRmax) to
 172 208bpm (103%HRmax). Peak speeds recording during the event was 26.39km/hr by the
 173 winning female and the highest average speed recorded being 10.8km/hr (3.0m/s) from the

174 winning male. There was a moderate, positive correlation between the participant's distance
 175 covered and their race results. This relationship was not significant ($p=0.385$).

176

177 **Table 2: Participant demographics and GPS results. Values presented are mean(\pm SD)**

Parameter	Group (n = 9)	Males (n = 6)	Females (n = 3)
Age (yrs)	34.78 \pm 11.49	31.11 \pm 12.32	41.67 \pm 6.43
Height (cm)	172.14 \pm 7.50	176.38 \pm 4.55	163.67 \pm 3.51
Weight (kg)	72.03 \pm 10.13	77.67 \pm 6.85	60.77 \pm 2.70
BMI (kg/m ²)	24.17 \pm 2.55	24.88 \pm 2.70	22.73 \pm 1.79
Years Competition (yrs)	5.39 \pm 1.65	5.08 \pm 1.91	6.00 \pm 1.00
Ranking	5-24 International 2-10 National	5-24 International 5-10 National	6-24 International 2-5 National
Course completion time (min)	83.37 \pm 7.47	79.87 \pm 4.10	90.40 \pm 8.37
Course distance covered (m)	13564.65 \pm 157.05	13508.97 \pm 128.44	13676.02 \pm 171.76
Peak speed (m/s)	21.27 \pm 0.70	20.95 \pm 2.24	21.90 \pm 3.91
Average speed (m/s)	9.78 \pm 0.70	10.13 \pm 0.53	9.07 \pm 0.41
Distance per minute (m)	163.21 \pm 12.68	169 \pm 9.19	151.63 \pm 11.43
Average heart rate (bpm)	168.56 \pm 9.79	172.00 \pm 10.32	161.67 \pm 3.21
Peak heart rate (bpm)	187.00 \pm 13.52	194.17 \pm 9.87	172.67 \pm 5.03

178

179

180 **DISCUSSION**

181 Previously, no scientific literature was available on the physiological (HR) demands and time
 182 motional analysis of a marathon SUP event. This study aimed to provide an understanding of
 183 the requirements of such a race and how extrinsic variables may influence race results and
 184 tactics. The majority of times, participants were in steady state with regard to speed and HR
 185 however peak speed occurred when the participant was paddling toward shore and when
 186 catching open ocean swell lines, the latter being highly advantageous to achieving a shorter
 187 race time.

188

189 The heart rates were variable in this race partly due to the variation in ages (18-55yrs). The
190 national competition is divided into open men's and women's, over 40's and over 50's.
191 Although age limits maximum heart rate, all athletes were able to maintain their heart rates
192 above 150bpm for the duration of the race. The lowest heart rates were seen at the beginning
193 of the race where they increased rapidly and were maintained for the majority of the race at
194 80-100% of their HRmax. Participants spending almost 90% of the race within 80-100% of
195 their age predicted HRmax comparable to previous research in windsurfing with participants
196 required to maintain between 87.4% to 92% of HRmax for the duration of their events (2, 3).
197 Road cyclists have been reported to maintain heart rates of 80-89% of HRmax during time
198 trials over 10-50km(11) and 84.1-90% HRmax in mountain biking (5, 6).

199

200 The low correlation ($r=0.384$) between the distance covered by SUP participants and the race
201 results demonstrated that SUP race tactics are critical in race results, the shortest distance
202 covered was recorded by a participant who was the seventh across the line. Some of the
203 participants chose a route which was not the shortest distance to the line from a point to point
204 perspective but allowed them to maintain a higher average speed for the duration of the race.
205 The utilisation of tactics may also explain the spread of the field up to 660 meters during this
206 event. The participants finishing in higher places were able to obtain a higher average speed
207 through the duration of the event possibly by regularly catching small waves and utilizing
208 swell lines in the direction of the wind on the day. Although this strategy may result in a SUP
209 participant paddling a greater total distance, the average speed of the participant remained
210 high, therefore ensuring completion of the event in the shortest amount of time.

211

212 This variation in total distance covered due to environmental conditions is similar to what has
213 been previously published in windsurfing events with distances covered having a standard
214 deviation of over 5km (12). This is primarily due to the participants seeking out the best
215 extrinsic conditions to maximise their speed across the water. This is most likely the
216 explanation for the variation of over 500m in total distance covered between athletes in this
217 race.

218

219 There were some limitations in this study. Global positioning analysis of this sport is ideal in
220 populated areas due to accessibility, the ability to closely monitor the athlete and availability
221 of satellites for the GPS units. However, the initial aim of this study was to investigate the
222 Molokai to Oahu challenge in Hawaii. Although initially the 15Hz GPS units worked well,
223 the remoteness of the location resulted in a drop out from satellite coverage. The 15Hz units,
224 despite being more accurate, require a greater number of satellites to be able to log data. It is
225 suggested for future studies; researchers ensure adequate satellite coverage in the location of
226 the SUP events.

227

228 **PRACTICAL APPLICATIONS**

229 This study provides athletes and coaches with data on the physiological requirements of
230 marathon SUP events and highlights the importance of race tactics. Marathon SUP events
231 require near maximal heart rates for the duration of the race, meaning a high aerobic capacity
232 is required for success in this format. Training intensities therefore need to replicate this high
233 aerobic demand. Coaches and athletes need to acknowledge the effect that extrinsic variables
234 during a race will have on optimum course selection, race speeds and consequently the
235 shortest race times. It could be suggested that athletes arrive early to competition locations in
236 order to adequately prepare for the local conditions (winds, tides, currents, swell). These

237 findings are applicable for both SUP athletes and coaches to assist with sports specific
 238 training sessions and understand the influence of race tactics on overall results.

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