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**Effects of an Offshore Sailing Competition on Anthropometry, Muscular Performance, Subjective Wellness and Salivary Cortisol in Professional Sailors.**

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## 1 Abstract

2 **Introduction:** Evidence regarding the impact of offshore sailing on fatigue and readiness  
3 variables is conspicuous by its absence. This study investigated the acute effects of an offshore  
4 sailing regatta on anthropometry, muscular performance, subjective recovery and salivary  
5 biomarker cortisol. **Methods:** Ten professional offshore sailors from a mixed-sex crew partook  
6 in the study (n = 10; mean  $\pm$  SD; age =  $32.2 \pm 3.96$  years; stature =  $179.1 \pm 7.30$  cm; body mass  
7 =  $84.2 \pm 12.1$  kg). The race involved three offshore legs over a 3-week period. Baseline  
8 measures of anthropometry, lower- and upper body muscular function, perceptions of  
9 subjective wellness and salivary cortisol were assessed 3-hours prior to competition (i.e., before  
10 the first leg). These measures were repeated within 30-min after the cessation of each event  
11 leg. During each leg, boat movements were recorded via global positioning system units.  
12 **Results:** There were significant reductions in lower- (ES = 0.49) and upper muscular (ES =  
13 0.21) functions as well as in subjective wellness (ES = 1.65). Salivary cortisol levels increased  
14 (ES = 0.84) **Conclusion:** These results demonstrate that, during an intensified period of sailing  
15 competition, fatigue will progressively increase. This may impede sailing performance by  
16 reducing physical and cognitive efficiency. Furthermore, counter movement jump, handgrip  
17 strength, perception of subjective wellness and cortisol concentration appear to be sensitive  
18 measures for monitoring fatigue and readiness in professional sailors.

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## 32 **Introduction**

33 Offshore sailing is a strategy-based sport that is intermittent in nature, with periods of high  
34 intensity activity (e.g., stacking, trimming and grinding) and low intensity recovery (e.g.,  
35 standing and sleeping)<sup>1</sup>. Depending on the nature of the race, vessels are sailed by lone sailors  
36 or crews and can last from days to months. Over the course of a crewed boat race, such as The  
37 Ocean Race (TOR), sailors are required to compete for many days during legs that rally the  
38 host cities. Few days are given to recover in between legs. Therefore, sailors need to recover  
39 quickly to start the following leg in an optimal state of readiness. Although studies from other  
40 team sports have outlined the acute effects of workload (WL) on anthropometrical,  
41 physiological and psychological variables<sup>2-3</sup>, the research conducted in a professional offshore  
42 crew-sailing environment is scarce<sup>4-5</sup>. Moreover, given the physical demands imposed during  
43 sailing, sailors typically experience high physiological stress and prolonged symptoms of  
44 fatigue<sup>6</sup>. This is in part due to the various weather conditions and the extensive physical  
45 demands of manoeuvring. Indeed, to optimize the vessel's speed, a sailor must be able to  
46 withstand high levels of physiological stress associated with weather conditions (temperature,  
47 wind, and sea state)<sup>7</sup>. To counterbalance the movement of the boat, and thus promote faster  
48 speed, stacking and trimming sails on deck requires high levels of physical readiness<sup>7</sup>. Sailors  
49 must also adapt to sleep deprivation and little comfort (nutrition, noise and hygiene) in order  
50 to limit impairments on cognitive performance, necessary for establishing routing strategies  
51 and evaluating weather forecasts. Past studies have investigated the impacts of sailing bouts on  
52 neuromuscular functions, energy demands and stress hormones. These studies have reported  
53 increases in neuromuscular fatigue<sup>4</sup>, muscular damage<sup>8</sup>, cognitive impairment<sup>9</sup>, motion  
54 sickness<sup>10</sup> and elevated cortisol levels after sailing bouts<sup>11</sup>. Although the current literature  
55 suggests that significant fatigue is induced by offshore sailing, little evidence is available in a  
56 crewed context. For this reason, monitoring the physiological and psychological adaptations  
57 from competition are thought to be important. Indeed, this can provide a better understanding  
58 of the demands of the sport and, thus, help bridge the gap between theory and practice for  
59 offshore sailing performance pathways.

60 Therefore, the aim of this study was to provide an overview of offshore sailing demands by a)  
61 documenting the characteristics of the race b) investigating the physiological responses to  
62 competition and c) examining the neurophysiological and psychological fatigue patterns in a  
63 professional mixed-sex crew. It was hypothesized that offshore sailing would 1) provoke body

64 composition turnover, 2) decrease muscular performance and 3) generate stress and perception  
65 of fatigue.

66

## 67 **Methods**

### 68 **Subjects**

69 Ten (8 males and 2 females) professional sailors (mean  $\pm$  SD; age:  $32.2 \pm 3.96$  years; stature :  
70  $179.1 \pm 7.30$  cm; body mass :  $84.2 \pm 12.1$  kg) volunteered to participate in the study. There  
71 were no reported injuries or diseases that would impair physical performance from any subject.  
72 Before starting the protocol, sailors attended a presentation and received information outlining  
73 the experimental procedures. The study protocol was approved by the ethics committee of  
74 Rennes University, France. Written informed consent was obtained from all subjects prior to  
75 the commencement of the study and all subjects were free to withdraw from the study at any  
76 time without penalty.

77

### 78 **Design**

79 All data was collected during a renowned international offshore sailing venue over a 3 weeks  
80 period. The TOR 2021 competition took place in June. All sailors competed in the same crew  
81 and had been training for 7 months preceding the race. Anthropometric measurements,  
82 muscular function testing, subjective recovery markers and salivary cortisol (SC) were  
83 obtained during baseline measurements (BSL) and after each of the 3 legs (Post<sub>1-3</sub>). The testing  
84 protocol was adjusted to fit the complexity of the sport. BSL measurements occurred 3 hours  
85 before the start of Leg 1 and Post<sub>1-3</sub> occurred within 30 min of docking in. Over the 3 weeks  
86 study period, data from 10 days of sailing was collected and analysed (Figure 1). Testing was  
87 conducted at the team's base, located in the different host cities, to ensure minimal disruption  
88 to the recovery process. Throughout the competition period, athletes were monitored by a  
89 qualified team doctor, physiotherapist, strength and conditioning coach and nutritionist. During  
90 recovery days, sailors underwent light cardiovascular activation (e.g., 20 min of jogging at 60%  
91 of maximal heart rate), sports massage and mobility sessions (e.g., static and dynamic  
92 stretching).

93

## 94 **Methodology**

### 95 **Baseline Measures**

96 On the morning of the first day of competition, 3-hours prior to starting Leg 1 of TOR, sailors  
97 underwent the testing battery. The crew was at the end of a tapering week and therefore had  
98 not participated in high intensity training the week prior to testing. The testing battery consisted  
99 of anthropometric measurements, fitness testing, wellness questionnaire control and SC  
100 collection. To account for diurnal variation, SC was collected within 1-hour of waking up,  
101 between 7:00-8:00 AM. The results from the first testing battery established the BSL.

102

### 103 ***Testing Battery***

#### 104 *Anthropometric measurement.*

105 Anthropometric characteristics were measured in the following order: body mass and skinfolds.  
106 A weighing scale (Seca®, Hamburg, Germany) was used to measure body mass. Measurements  
107 for body mass were made with an accuracy of 0.1 kilograms (kg). Three skinfolds ( $\Sigma$  3  
108 Skinfold) were taken on the right side of each sailor (male: pectoral, abdominal and thigh;  
109 female: triceps, abdominal and thigh) according to recommendations by Jackson and Pollock<sup>12</sup>.  
110 The skinfolds were measured with a Harpenden skinfold caliper (Harpenden®, Burgess Hill,  
111 UK) with 10 g.mm<sup>-2</sup> of constant pressure. Body density was assessed while body fat (BF) was  
112 calculated using Brozek's equation<sup>13</sup>. Lean body mass (LBM) was calculated by subtracting  
113 BF from total weight.

#### 114 *Muscular performances*

##### 115 **Countermovement Jump**

116 Lower body power was tested on the countermovement jump (CMJ) using a chronojump  
117 contact mat (Chronojump-Boscosystem™, Software, Spain). Each sailor completed three  
118 attempts with 1 min of rest between trials. For the execution of each attempt, a countdown of  
119 “3, 2, 1, jump” was indicated orally. All attempts were completed with sailors placing arms  
120 akimbo to avoid movement disruption. Sailors were instructed to perform a rapid eccentric  
121 phase, immediately followed by an explosive concentric contraction with the intention to jump  
122 as high as possible. The height of the best CMJ performance was reported for analysis.

## 123 Handgrip strength

124 Maximal isometric hand-grip strength (HGS) was assessed with a Jamar® handgrip  
125 dynamometer (Sammons Preston Corp., Bolingbrook, Ill., USA). The test positions were  
126 standardized<sup>13</sup>. Three trials were performed on each hand. The first three trials started with the  
127 right hand. Sailors were instructed to squeeze the device as hard as possible for 3 s. The time  
128 between each trial was 15 s and 3 min of rest was given when changing hands. The maximal  
129 measure of the three trials was retained in Kg. Sum (HGS<sub>sum</sub>) of both, dominant hand (HGS<sub>d</sub>)  
130 and non-dominant hand (HGS<sub>nd</sub>), measures were assessed and included in the results.

## 131 *Subjective Recovery Status*

132 The Hooper-Index (HI) was measured using a customized questionnaire based on the  
133 recommendations of Hooper and Mackinnon<sup>15</sup>. Levels of sleep quality (HI<sub>sleep</sub>), delayed onset  
134 muscle soreness (HI<sub>doms</sub>), stress (HI<sub>stress</sub>) and fatigue (HI<sub>fatigue</sub>) were scored on a 7-point scale  
135 on which “1” and “7” represent “very, very good” and “very, very poor” respectively. The  
136 Hooper-Index was computed by summing its four subgroups. It was applied 30 min after the  
137 leg arrival (Post<sub>1-3</sub>). All questions and answers were completed individually.

## 138 *Salivary Stress Marker*

139 Sailors’ saliva samples were collected upon waking (between 7:00 and 8:00 am). To ensure  
140 more rigorous testing and to limit cortisol measurement errors, sailors were required to refrain  
141 from eating, brushing their teeth and chewing gum prior to testing. Sailors placed the swab  
142 (Soma Bioscience, Wallingford, United Kingdom) on their tongue and closed their mouth.  
143 When the indicator on the swab’s stem turned blue, the test was considered complete (swab  
144 collected 0.5 mL of oral fluid). The swab was then placed in the buffer bottle of assay (sodium  
145 phosphate, salts, detergents and preservatives) before gently mixing the sample for 2 min. Two  
146 drops of the sample were then placed in the window of the lateral flow device. The device was  
147 left still during the incubation period (10 min). The strip was then placed in the real-time reader  
148 and the results were ready within 20 s. SC was then collected as nanograms per millilitre  
149 (ng/mL). Soma Bioscience oral fluid collector has been validated against enzyme linked  
150 immunosorbent assay (ELISA) and have been proven as a reliable method to collect and  
151 analyse SC<sup>16</sup>.

152

153

## 154 ***Race analysis***

### 155 *Internal Sailing Load*

156 Subjective internal load was estimated using the session-rating of perceived exertion (s-RPE),  
157 with ratings (Borg 0-10 scale) obtained from each individual sailor within 30 min of completing  
158 each leg. Each sailor was familiarized with the scale before starting the study. The obtained  
159 value was multiplied by the time sailed (in minutes) during the leg to register a sailing load in  
160 arbitrary units (AU)<sup>17</sup>.

161

### 162 *External Sailing Load*

163 Race data - including sailing distance, average speed, course coverage and manoeuvre count  
164 (tack and gybe) were collected during the 3 legs of competition. Data was made available  
165 through Global Positioning System (GPS) units and shared by the navigation specialist of the  
166 team. Route and manoeuvre count were measured by the official TOR tracker.

167

### 168 ***Energy intake***

169 Energy intake (EI) was measured to prepare individual meal plans prior to TOR. Basal  
170 metabolic rate (BMR) was calculated using the Schofield equation<sup>18</sup> and was multiplied by a  
171 physical activity coefficient which was determined by categorizing each position on-board by  
172 its physical demands<sup>19</sup>. Individual EI was prepared before each leg and controlled upon arrival  
173 by the human performance practitioner.

174

## 175 **Statistical Analysis**

176 Data was calculated through standard statistical methods and is presented as mean  $\pm$  standard  
177 deviation. All variables were considered normally distributed through analysis with the  
178 Shapiro-Wilk test, histograms and skewness values prior to analysis. One way ANOVA with  
179 repeated measures was used to determine the differences between the different parameters  
180 during the 3 legs. When results were significantly different, an effect size (ES) calculation was  
181 used. ES was evaluated using Cohen's *d* along with 95% confidence intervals (CI). ES of  $\leq 0.2$ ,  
182 0.21-0.60, 0.61-1.20, 1.21-2.0,  $\geq 2.0$  were considered as trivial, small, moderate, large and very  
183 large, respectively<sup>20</sup>. Statistical analyses were performed using the SPSS package (15.0  
184 version; SPSS, Inc., Chicago, IL, USA). The level of significance was set at  $p < 0.05$ .

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## Results

188 Table 1 shows the external and internal load parameters across the 3-legs of TOR. A total of  
189 5167 km was sailed in 10 days 4h 31 min at an average speed of 5.87 m.s<sup>-1</sup>. 88 manoeuvres  
190 (i.e., 53 tacks and 35 gybes) were performed with each one occurring every 58.7 km. Leg 1,  
191 the longest leg of the three, was characterised by its downwind nature, fast speed (i.e., 7.5 m.s<sup>-1</sup>)  
192 and accounted for 51 % of the total distance of TOR. Leg 2 reported to have the most tacking  
193 manoeuvres (i.e., 28) and also outlined a higher RPE (7.8 ± 2), although time at sea was the  
194 shortest of the three. It was characterized by its upwind nature and high manoeuvre frequency  
195 (1 every 2h 02 min). Leg 3 held the most manoeuvres (i.e., 35) and was characterised by its  
196 slow speed (i.e., 4.02 m.s<sup>-1</sup>).

197 The multilevel ANOVA (Table 2) found no significant difference in anthropometric parameters  
198 during the 3 legs of racing when compared to BSL. Differences were nevertheless observed at  
199 Post<sub>3</sub> for BF (p=0.004; ES = 0.25) when compared to Post<sub>2</sub>.

200 Compared with BSL (37.0 ± 8.0 cm), CMJ height (Figure 2) significantly decreased at Post<sub>2</sub>  
201 (33.1 ± 6.6 cm; p=0.05; ES = 0.53) and Post<sub>3</sub> (33.2 ± 7.7 cm; p=0.05; ES = 0.49). A significant  
202 decline was observed between Post<sub>1</sub> and Post<sub>2</sub> (p=0.007; ES = 0.58). Upper body strength  
203 (Figure 3) decreased for HGS<sub>sum</sub> when compared with BSL (113 ± 22.3 kg) at Post<sub>1</sub> (107.0 ±  
204 19.6 kg; p=0.01; ES = 0.29), Post<sub>2</sub> (102.4 ± 19.0 kg; p=0.001; ES = 0.51) and Post<sub>3</sub> (108.6 ±  
205 18.8 kg; p=0.05; ES = 0.21). Post<sub>2</sub> (p=0.03; ES = 0.24) and Post<sub>3</sub> (p=0.03; ES = 0.3) were  
206 significantly different from preceding legs. HGS<sub>d</sub> also decreased at Post<sub>1</sub> (55.4 ± 10.7 kg;  
207 p=0.002; ES = 0.44), Post<sub>2</sub> (52.9 ± 10.0 kg; p<0.001; ES = 0.62) and Post<sub>3</sub> (56.2 ± 10.4 kg;  
208 p=0.02; ES = 0.31) when compared to BSL (59.7 ± 11.9 kg). HGS<sub>d</sub> was significantly different  
209 from preceding legs at Post<sub>2</sub> (p=0.04; ES = 0.25) and Post<sub>3</sub> (p=0.02; ES = 0.33). HGS<sub>nd</sub> was  
210 only significantly different from BSL (53.3 ± 10.7 kg) at Post<sub>2</sub> (49.5 ± 9.5; p=0.02; ES = 0.37).

211 The Hooper Index (Figure 4) increased significantly at Post<sub>1</sub> (17.4 ± 2.9 AU; p=0.001; ES =  
212 1.43) and Post<sub>2</sub> (19.2 ± 2.7 AU; p=0.001; ES = 2.23) when compared to BSL (13.7 ± 2.2 AU).  
213 HI was significantly different between Post<sub>2</sub> and Post<sub>3</sub> (p=0.005; ES = 1.65). Sleep quality  
214 decreased significantly at Post<sub>1</sub> (4.6 ± 0.9 AU; p=0.04; ES = 1.05) and Post<sub>2</sub> (5.4 ± 1.1 AU;  
215 p=0.006; ES = 1.76) when comparing with BSL (3.7 ± 0.8 AU) and at Post<sub>3</sub> (p=0.04; ES =  
216 1.34) when comparing with preceding leg. Perception of fatigue was significantly different

217 from BSL ( $3.4 \pm 0.5$  AU) at Post<sub>3</sub> ( $4.2 \pm 0.9$  AU;  $p=0.04$ ; ES = 1.09). Stress at Post<sub>1</sub> ( $4.9 \pm 0.5$   
218 AU;  $p<0.001$ ; ES = 2.33) and Post<sub>2</sub> ( $5.7 \pm 0.6$  AU;  $p<0.001$ ; ES = 3.26) was significantly  
219 different to BSL ( $3.2 \pm 0.9$  AU). Muscle soreness did not differentiate with BSL ( $3.4 \pm 0.7$  AU)  
220 during the race.

221 SC levels (Figure 5) varied throughout the competition. Post<sub>1</sub> ( $18.6 \pm 5.6$  ng/mL;  $p=0.005$ ; ES  
222 = 1.44), Post<sub>2</sub> ( $14.2 \pm 2.9$  ng/mL;  $p=0.03$ ; ES = 0.76) and Post<sub>3</sub> ( $16.2 \pm 6.7$  ng/mL;  $p=0.02$ ; ES  
223 = 0.84) were all significantly different from BSL ( $11.5 \pm 4.1$  ng/mL). Variation with preceding  
224 legs was significant at Post<sub>2</sub> ( $p=0.03$ ; ES = 0.97).

## 225 Discussion

226 The hypotheses initially stated were globally validated since body composition was partially  
227 modified, muscular performance decreased and objective and subjective fatigue were observed  
228 during and after the competition.

229 Although previous research in sailing have observed weight loss, fat percentage and lean body  
230 mass decreases after competition<sup>1,5,9,29</sup>, the results of the current study found only significant  
231 changes in BF (%) at Post<sub>3</sub>. Indeed, during the 3-weeks of competition, when comparing BSL  
232 levels with post<sub>1-3</sub>, no significant differences were observed. A potential reason for  
233 differentiation with other research may be due to sailors being tested extensively to determine  
234 their individual energetic needs on-board. Previous research has highlighted that loss in body  
235 mass and, more particularly, lean body mass decrease, could eventually hinder physical and  
236 cognitive performance<sup>21</sup>. It was therefore essential to provide the sailors with the adequate EI  
237 as they were confronted to irregular biological rhythm, sleep deprivation, incessant  
238 compensatory muscle activity and continuous stress<sup>5</sup>. Elevated EI values (i.e., 15-17 MJ.day<sup>-1</sup>)  
239 have been reported in other research with considerable weight loss still being observed<sup>5</sup>.  
240 Nevertheless, it should be noted that the legs studied here were shorter and occurred in warmer  
241 climate. Also, daily protein consumption was more important in the present study (23% vs.  
242 14% in the previous study mentioned<sup>5</sup>) and could explain, in part, the maintenance of LBM<sup>22</sup>  
243 throughout TOR.

244 The results from the current study confirm that sailors experienced a significant decline in CMJ  
245 height (Figure 2) during and after TOR. Similar responses during competition have been  
246 observed across various “long distance sports”<sup>23</sup>. A decrease in lower body strength and power  
247 abilities immediately after sailing is common in professional sailors<sup>24</sup>. However, this study  
248 provides new insights that, to the author’s knowledge, have never been investigated in

249 professional crews. Indeed, contrarily to past research, the sailors in this study did not suffer  
250 from body mass loss and/or muscle wastage during the competition. These results are in line  
251 with findings highlighting muscular function impairment due to the yawing, rolling and  
252 pitching motions (sway) of the hull<sup>25</sup>. Moreover, the downwind specificity of Leg 1 (i.e., 22  
253 gybes) elicited no impairment to lower body muscular function contrarily to Leg 2 and Leg 3,  
254 which were mainly upwind. Upwind legs seemed to affect lower limbs muscular function more  
255 than the downwind leg despite Leg 1 being two times longer than Leg 2 and Leg 3 (Table 1).  
256 This alteration may be linked with the constant swaying of the hull caused by swell in upwind  
257 sailing conditions. Indeed, maintaining constant proprioceptive tension, due to hull movement,  
258 seems to increase the mechanical loading of hip extensors and hip flexors.

259 HGS (Figure 3) has received a considerable amount of interest in previous research. Indeed, it  
260 has been associated with greater upper body strength, ballistic performance, lean body mass<sup>26</sup>,  
261 athlete level differentiation<sup>27</sup> and success<sup>28</sup>. The offshore sailors in our study reported superior  
262 HGS<sub>d</sub> at BSL compared to other offshore sailing research (i.e., in the present study  $59.7 \pm 11.9$   
263 kg vs.  $53.6 \pm 8.3$  kg and 40 kg in previous studies<sup>4,29</sup>) and similar to crewed dinghy racing ( $61.1$   
264  $\pm 9.5$  kg in another study<sup>28</sup>). Indeed, the physical WL associated with grinding, hoisting,  
265 stacking and trimming the sails is intense and requires a fair amount of grip strength.  
266 Nevertheless, previous research reported that HGS performance was preserved after offshore  
267 sailing competition<sup>4,29</sup>. However, in this current research, the sailors observed a progressive  
268 decay of maximal strength in HGS during each leg. The decrease in performance detected in  
269 our study could be explained by the specific physical demands of the vessel used in TOR.  
270 Indeed, the racing conditions are known to be more extreme and the boat harder to handle due  
271 to its low displacement and facilitation to plane<sup>5</sup>. Hence, we can assume that the sailors  
272 underwent extensive upper body solicitation during TOR and suffered from high levels of  
273 neuromuscular fatigue.

274 The Hooper Index and its subsets (i.e., sleep quality, fatigue, stress and muscle soreness) has  
275 recently been shown to be a promising tool for monitoring indices of fatigue and preparedness  
276 in many sports<sup>30</sup>. However, research examining the effects of sailing on subjective recovery  
277 variables is scarce<sup>29</sup>. Indeed, research has mainly focused on sleep quality and highlights the  
278 effects of sleep deprivation on cognitive performance<sup>8</sup>. These studies have put forward the need  
279 to identify an optimal balance between wakefulness and planned sleeping to optimize sailing  
280 performance. The results in our study (Figure 4) found that HI<sub>sleep</sub> and HI<sub>stress</sub> were more  
281 pronounced during the legs where the RPE was higher (i.e., Post<sub>1</sub> and Post<sub>2</sub>). In spite of the

282 multiple physical stressors involved in sailing,  $HI_{\text{doms}}$  was preserved during TOR, whereas  
283  $HI_{\text{fatigue}}$  increased linearly throughout the race and was significantly different from BSL at  
284  $\text{Post}_3$ . Nevertheless, it should be noted that sailors were provided protein supplementation on-  
285 board and in-between legs to optimize muscular recovery<sup>31</sup> and to avoid muscle atrophy linked  
286 to the accumulation of high levels of cortisol during sailing<sup>9</sup>. In fact, sailors had been training  
287 regularly 7-months prior to competition which could have generated morphological adaptations  
288 in the muscle fibres necessary to withstand the induced mechanical stress without causing  
289 structural alterations.

290 Intensified WL periods have been found to increase cortisol concentration<sup>32</sup>. This hormonal  
291 increase has been associated to stress tolerance disturbances and decreases in performance.  
292 Studies in other long distance/duration sports have shown that athletes experienced greater  
293 concentration of SC in post competition phases<sup>33</sup>. In sailing, few studies have considered  
294 analysing catabolic hormone alterations despite significant increases in cortisol concentration  
295 being observed at sea<sup>34</sup>. Indeed, sailors in the current study showed an elevation of SC levels  
296 at  $\text{Post}_{1-3}$  (Figure 5) which corresponded to the s-RPE fluctuations observed during the legs  
297 (Table 1). Moreover, HI did not differentiate from BSL at  $\text{Post}_3$  despite its' correlation to SC<sup>35</sup>.  
298 This finding may be due to the crew's winning performance during the final leg. Indeed,  
299 subjective wellness seems to be associated with competition outcome<sup>36</sup>. Nevertheless, it was  
300 found that SC levels increased significantly after intense bouts of offshore sailing. This seems  
301 to be in line with other studies analysing the effects of prolonged change of circadian rhythms  
302 in confined environments<sup>37</sup>.

303

## 304 **Practical Application**

305 This study has revealed a number of practical applications that are relevant to human  
306 performance practitioners and sailors alike. Over an intensified period of offshore sailing  
307 competition, when there is insufficient time to recover between legs, physiological and  
308 psychological fatigue accumulates. Impaired readiness when sailing may compromise the  
309 boat's performance by reducing physical and cognitive capabilities. As such, cautious WL  
310 monitoring should be implemented by practitioners during a competitive phase to determine a  
311 sailor's readiness and recovery status. Upper body and lower body muscular capabilities, as  
312 well as SC, were impacted by an offshore sailing competition and markers obtained from CMJ  
313 and HGS appear to be sensitive ways of detecting muscular fatigue. Questionnaires that assess

314 subjective wellness parameters are useful tools for monitoring fatigue and recovery during  
315 offshore sailing competition. Such questionnaires are non-invasive and non-expensive tools  
316 that can be used frequently to provide useful information on an athlete's readiness to sail. This  
317 research was conducted over a reduced 3-week competition as an adaptation to the current  
318 covid-19 crisis. Future research, during longer events, is required to investigate the dose-  
319 response relationships between sailing WL and monitoring markers. Larger sample sizes would  
320 also allow further exploration of activity profiles, according to crew position, on-board. In  
321 addition, as laboratory measures are expensive markers, further investigations are needed to  
322 examine the relationship between external WL parameters and subjective markers of recovery  
323 found in questionnaires. Furthermore, through the use of micro-captors and video analysis,  
324 researchers could observe position specific activity and determine the physical and  
325 physiological demands for each maneuver and/or sailing situation<sup>38</sup>.

326

## 327 **Conclusion**

328 To the best of our knowledge, this is the first longitudinal study to provide information on the  
329 effects of offshore sailing on physiological parameters and fatigue patterns in a professional  
330 mixed-sex crew sailing team. This investigation confirmed (i) very little effect on  
331 anthropometric parameters (ii) significant decreases in lower- and upper body muscular  
332 abilities, (iii) significant variations of wellness parameters during the different legs and (iiii)  
333 increases of SC stress hormone during and after competition. Therefore, the current study  
334 presents the impacts that offshore sailing has on athletes. The results will provide helpful  
335 information for sports scientists, sailing coaches and performance practitioners to appropriately  
336 manage the training and recovery processes in their quest to optimize human performance.

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489 **Tables and Figures**490 **Table 1.** External and internal load of TOR.

Variables	Leg 1	Leg 2	Leg 3	Total
<i>External load</i>				
Course distance (km)	2411.3	1074.2	1070.5	4556.0
Distance sailed (km)	2655.8	1299.9	1211.8	5167.5
Course coverage (%)	110	121	113	113.5
Time at sea	4 days 1h 8 min	2 days 15h 31 min	3 days 11h 52 min	10 days 4h 31 min
Total manoeuvres	22	31	35	88
<i>Tacks</i>	0	28	25	53
<i>Gybes</i>	22	3	10	35
Manoeuvre / time	4h 24 min	2h 02 min	2h 29 min	2h 47 min
Average speed (m.s <sup>-1</sup> )	7.5	5.68	4.02	5.87
<i>Internal load</i>				
RPE	7.45 ± 2.2	7.8 ± 2.0	5.85 ± 1.4	
s-RPE (AU)	43418.6 ± 12548.8	29725.8 ± 7579.5	30490.2 ± 7477.6	

491 Tack: Upwind Manoeuvre; Gybe: Downwind Manoeuvre; s-RPE: Session Rate of Perceived Exertion.; AU: Arbitrary Units.

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504 **Table 2.** Description of body composition and energy intake throughout TOR.

Variables	BSL	Post <sub>1</sub>	Post <sub>2</sub>	Post <sub>3</sub>
<i>Body Composition</i>				
Body Mass (kg)	84.24 ± 12.7	83.79 ± 12.8	83.57 ± 12.8	84.38 ± 12.5
LBM (kg)	70.72 ± 11.4	70.66 ± 10.3	70.74 ± 10.6	70.42 ± 10.0
BF (%)	16.04 ± 5.6	15.66 ± 4.9	15.34 ± 4.9	16.54 ± 4.7 <sup>††</sup>
<i>Energy Intake</i>				
BMR (cal.day <sup>-1</sup> )	1802.67 ± 173.3			
Coefficient	2.23 ± 0.3			
EI (MJ.day <sup>-1</sup> )		15.57 ± 2.6	16.43 ± 2.5	16.8 ± 2.6
<i>Carbohydrates (%)</i>		57.34 ± 11.7	54.42 ± 12.2	56.75 ± 8.6
<i>Protein (%)</i>		21.55 ± 4.1	23.3 ± 6.4	24.2 ± 5.7
<i>Fat (%)</i>		21.11 ± 8.5	23.28 ± 7.3	19.05 ± 4.3

505 BSL: Baseline; Post<sub>1-3</sub>: Measurements obtained after Leg1-3; LBM: Lean Body Mass; BF: Body Fat; BMR: Basal Metabolic Rate; EI:  
506 Energy Intake. †† Significant difference with values of preceding Test; p≤0.01.

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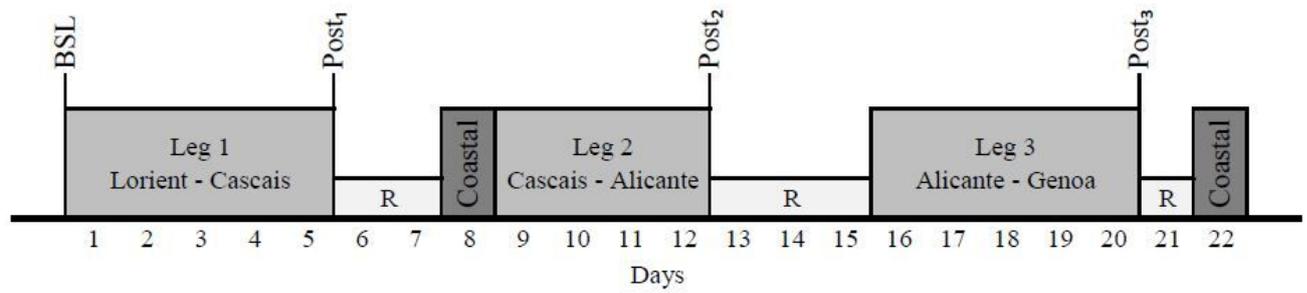
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521 **Figure 1.** Timeline of TOR 2021 and assessments during 3 weeks of study. BSL: Baseline; Post<sub>1,3</sub>: Measurements obtained  
522 after Leg1-3; R: Recovery.

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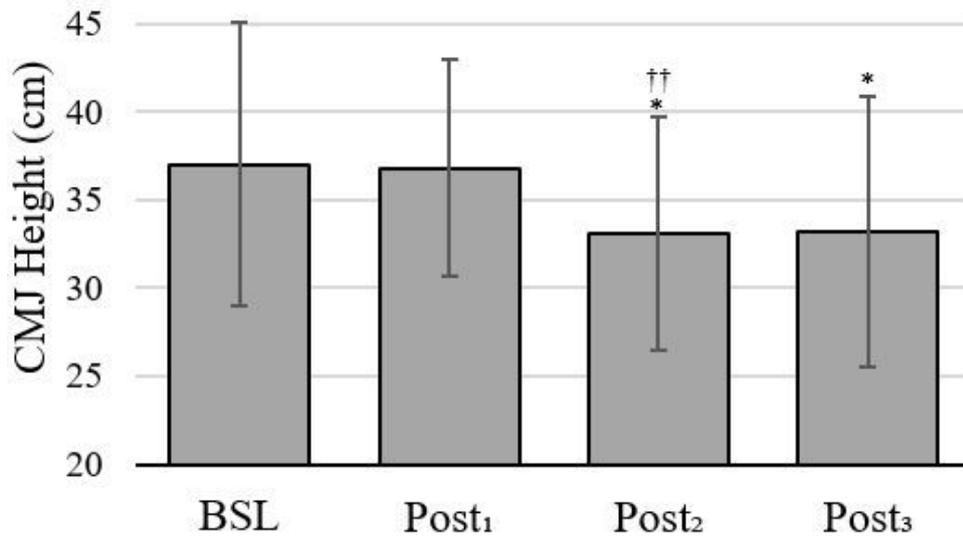
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538 **Figure 2.** Changes in countermovement jump height throughout TOR. BSL: Baseline Level; CMJ: Countermovement Jump;  
539 Post<sub>1-3</sub>: Measurements obtained after Leg1-3. \* Difference is significant to BSL at  $p \leq 0.05$ ; †† Significant difference with  
540 values of preceding Test;  $p \leq 0.01$ .

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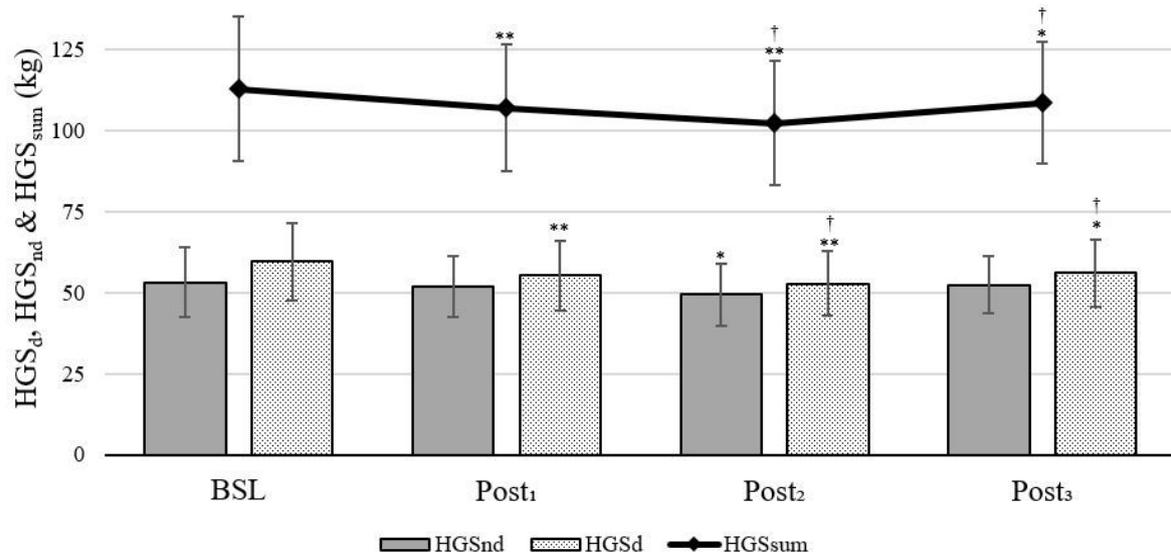
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552 **Figure 3.** Changes in handgrip strength throughout TOR. HGS<sub>d</sub>: Dominant Handgrip Strength; HGS<sub>nd</sub>: Non-Dominant553 Handgrip Strength; HGS<sub>sum</sub>: Sum of HGS<sub>d</sub> and HGS<sub>nd</sub>; BSL: Baseline Level. \* Difference is significant to BSL at  $p \leq 0.05$ . \*\*554 Difference is significant to BSL at  $p \leq 0.01$ . † Significant difference with values of preceding Test;  $p \leq 0.05$ .

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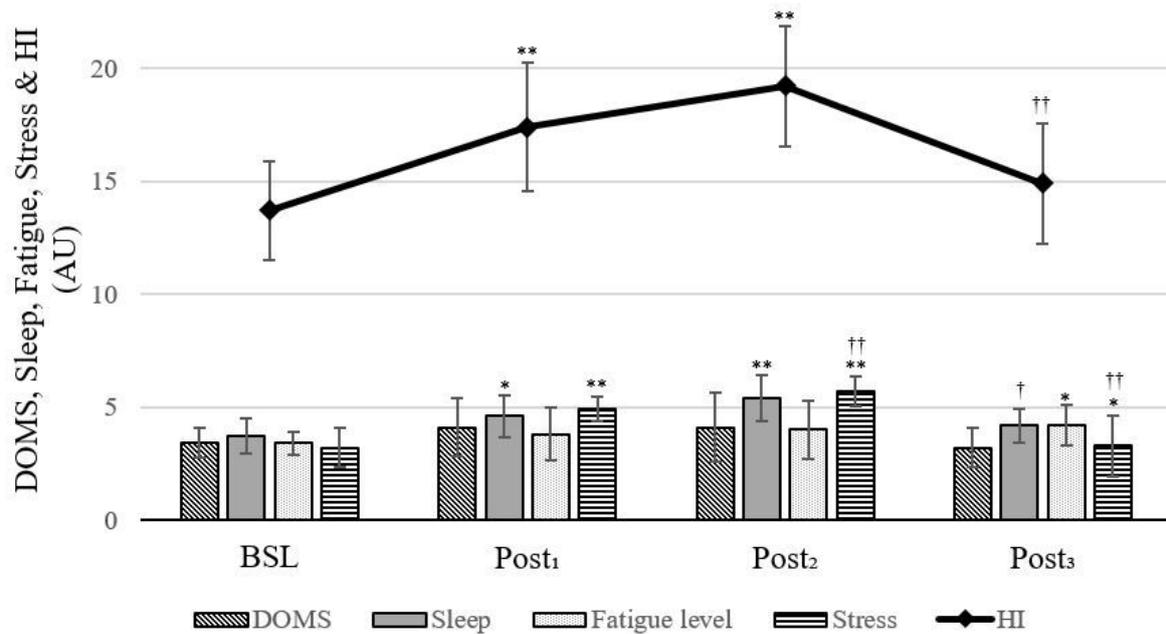
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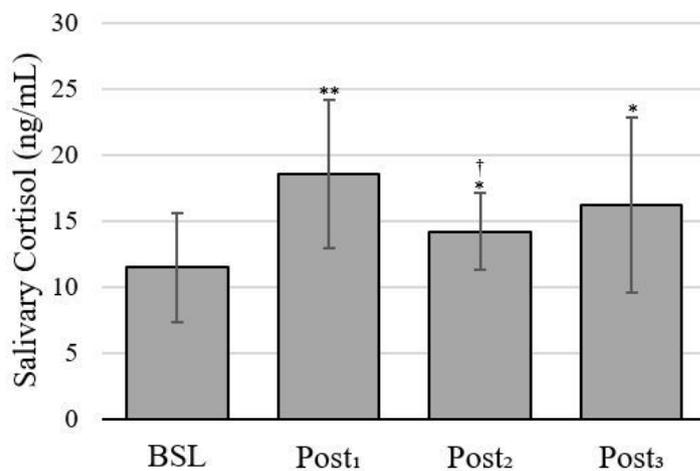
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570 **Figure 4.** Changes in subjective wellbeing parameters and Hooper Index during TOR. DOMS: Delayed Onset Muscle  
 571 Soreness; HI: Hooper Index; BSL: Baseline Level. \* Difference is significant to BSL at  $p \leq 0.05$ . \*\* Difference is significant  
 572 to BSL at  $p \leq 0.01$ . † Significant difference with values of preceding Test;  $p \leq 0.05$ . †† Significant difference with values of  
 573 preceding Test;  $p \leq 0.01$ .

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576 **Figure 5.** Changes in salivary cortisol during TOR. BSL: Baseline Level. \* Difference is significant to BSL at  $p \leq 0.05$ .  
 577 \*\*Difference is significant to BSL at  $p \leq 0.01$ . † Significant difference with values of preceding Test;  $p \leq 0.05$ .