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Descriptive Analysis of Olympic Class Windsurfing Competition during the 2017-2018 Regatta Season

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Abstract

The aim of the present study was to describe race characteristics of top three finishers for different wind speed categories within Olympic windsurfing competition. Global position system data was analysed from 94 races (47 Men's races & 47 Women's races) across five regattas during the 2017-2018 windsurfing season. Medium wind speeds (8.1 to 15.9 kts) represented the greatest proportion of races for Men (43 %) and Women (34 %). Large variations in race time (825 – 2105 s), distance (2167 – 11786 m) and board speeds (3.32 – 16.78 kts) were experienced across the wind categories. Although race time for Women was non-significant ($P = 0.101$) between wind categories. Low 1st windward mark position was reported in both Men (1st = 2.2 ± 2.1, 2nd = 3.7 ± 2.6, 3rd = 5.0 ± 3.3) and Women (1st = 2.2 ± 1.9, 2nd = 3.5 ± 2.2, 3rd = 4.0 ± 2.8) who finished on the podium. The findings may provide useful information to coaches and sport scientists in the planning and implementation of specific training interventions. Furthermore, the detail of 1st upwind characteristics (time, distance, board speed and manoeuvres) could be used to enhance the ecological validity of laboratory-based testing.

Keywords: Windsurfing, Olympic, Pumping, Competition, GPS

Introduction

Windsurfing was first recognised as an Olympic sport in Los Angeles 1984. Barcelona 1992 marked the class expansion and inception of a separate Women's class. There have been two major changes since 1992 that have created a shift in the perception of board sailing from what was considered a moderately intense physical sport (McLean & Chad, 1992) to a highly physiologically demanding Olympic class (Guevel, Maisetti, Prou, Dubois & Marini, 1999; Vogiatzis & De Vito, 2014). Firstly, in 1993 World Sailing (Formally known as the International Sailing Federation) exempted rule 42 (Prohibited actions, 42.2a: *pumping: repeated fanning of any sail either by pulling in and releasing the sail or by vertical or athwartship body movement*) from the windsurfing class which therefore permitted the action of sail pumping in competition. Vogiatzis, De Vito, Rodio, Madaffari and Marchetti (2002) reported that pumping induced significant increases in $\dot{V}O_2$ and heart rate (HR) values when compared to non-pumping conditions. Secondly, the introduction of the new RS:X Olympic board was shown to enhance the boards' performance characteristics over the older Mistral One Design and consequently, increased cardiorespiratory demands of the new pumping technique associated with the RS:X board (Castagna, Brisswalter, Lacour & Vogiatzis, 2008).

Sail pumping in windsurfing is a manoeuvre in which a windsurfer pulls and pushes the sail rhythmically so that it acts as a wing, thus providing the board with additional propulsion (Vogiatzis, De Vito, Rodio & Marchetti, 2005). Pumping is considered particularly effective in wind speeds that are considered light (Vogiatzis et al. 2002). At higher wind speeds, this action loses its efficiency or the load becomes too great within the sail to pump (Castagna, Vaz Pardal & Brisswalter, 2007). Furthermore, key manoeuvres in all wind speeds, such as tacks and gybes will require a sailor to pump the sail powerfully to regain full board momentum and attain maximum board speed as quickly as possible.

As with all Olympic sailing classes, windsurfing is considered a highly complex sport in which tactical, technical, psychological and physical qualities contribute to successful performance outcomes (Bojsen-Møller, Larsson, Magnusson & Aagaard, 2007). However, as the action of sail pumping has such a profound influence on board speed in light winds, it results in a significant influence on performance outcomes in races (Castagna et al. 2007). The need for windsurfers to possess the necessary physiological characteristics is evident with windsurfers attaining some of the highest level of physiological characteristics (i.e. $\dot{V}O_{2\ max}$) amongst current Olympic classes (Bojsen-Møller, Larsson & Aagaard, 2014).

Although the importance of pumping is highlighted above, there is currently a dearth of literature understanding pumping performance within international RS:X windsurfing competitions with the majority of research conducted in simulated training or racing environments (Bojsen-Møller et al. 2014). This is partially explained by all personal electrical equipment and global positioning systems (GPS) units (with the exception of heart rate monitors) restricted by World Sailing and the RS:X class within competitive regattas. However, within World Sailing events it is a requirement for windsurfers to race with a tracker, with sanctions imposed on those who fail to launch without. Beyond World Sailing events, class associations run World and European championships with the use of GPS trackers at the digression of those respective associations. World Sailing event data is readily available through an online platform (https://www.sapsailing.com). The data can be used for derivative work and could therefore provide valuable additional performance-related information that can be of use to athletes, coaches and science and medicine staff.

GPS has been applied extensively in sports such as football, providing activity profiles for individuals, which include performance metrics as well as sport specific tasks (Aughey, 2011). Thus, a greater level of knowledge with regards to the external displacement data of those achieving low finishing positions across different wind speeds (i.e. Light vs. Heavy) could

provide a critical step to further the understanding of the physical demands of RS:X windsurfing competition performance. Specific components of a race can further be explored, such as 1st windward mark rounding position, which was highlighted in preliminary performance analysis data to be important to achieving a podium finish in a race. Such information might provide coaches and sport scientists with information in which to base planning, implementation and monitoring of training interventions. Therefore, the purpose of this study was threefold; (1) describe the distribution in wind speed categories experienced across the 2017-2018 windsurfing regatta season and the associated race time, distance sailed and average board speed for each wind category for both Men and Women. (2) Assess the importance of the 1st upwind leg on race outcome through analysis of windward mark (WWM) rounding positions. (3) In light wind races, describe the 1st upwind leg with regards to time taken to complete, distance sailed, average board speed and number of manoeuvres of those competitors achieving a top three WWM position.

Methods

Following ethical approval from the university research ethics committee, the study was based on retrospective analysis of GPS data regarding RS:X windsurfers competing in the 2017-2018 World Sailing World Cup series and the 2018 Hempel Sailing World Championships. The GPS analysis was included for all event races, where it was available. The top three finishing positions for both Men and Women were included and averaged to ascertain the race time, distance and average board speed.

Although other regattas have GPS available, World Sailing events were included due to the calibre of fleet which competed at these events. For the World Sailing World Cup series, it was Gamagori (Number of races = Men, 5 & Women, 7), Miami (Number of races = Men, 7 & Women, 8), Hyeres (Number of races = Men, 12 & Women, 11) and Marseille (Number of

races= Men, 10 & Women, 10). The 2018 Hempel Sailing World Championships in Aarhus (Number of races = Men, 13 & Women, 11) was also included due to its importance as the main outcome event of the Olympic Sailing calendar year. All data was analysed from the online SAP Sailing platform (https://www.sapsailing.com/. Accessed 9th January 2019). In total, 94 races were included for analysis. There were two Women's races from Marseille (Race 8 & 9) that were not included into any wind speed categorisation as the GPS data was not available.

Race analysis included the range of wind speed range during a race (and subsequently categorised) as well as the race total time (s), distance travelled (m) during the race and average board speed (kts) for the respective competitors. Competitors who finished in the top three race positions also had their 1st WWM rounding position recorded.

Race wind speeds were categorised in alignment with Castagna et al. (2007) with light wind defined as 4 to 8 kts and heavy wind as 16 to 22 kts. Therefore, the wind classifications for the present study were, light (< 8.0 kts), medium (8.1 to 15.9 kts) and heavy (> 16.0 kts). If a race wind range fell between two categories, it was classified as either light to medium or medium to heavy.

Pumping conditions were defined as those in light and light to medium wind speeds. In races which were categorised as light or light to medium further analysis was conducted on the 1st upwind leg. Competitors who rounded the 1st WWM in the top three had their time (s), distance sailed (m), average board speed (kts) and number of manoeuvres analysed.

Statistical analysis

Microsoft Excel software was used to analyse the distribution of race wind speeds. All other analysis was performed using SPSS statistical software (IBM SPSS Inc., Chicago, IL.). A one-way repeated measures ANOVA was employed to analyse any differences in the race time,

distance and speed for the five wind categories. Where significant differences were detected, *post-hoc* tests were conducted (with Bonferroni adjustment applied to the alpha level) to confirm where differences occurred between groups. Confidence interval (CI) for the mean was set at 90 % (Batterham & Hopkins, 2006). All data are reported as mean ± standard deviation (SD) unless otherwise stated.

Results

Wind speed distribution

Race wind speed distribution was highly varied for both Men and Women (Figure 1.). Medium wind speeds represented the greatest proportion of races wind speeds (Men = 43 % & Women = 34 %). Wind speeds categories (light and light to medium) that represent pumping conditions were present in 36 % of races for Men and 38% of races for Women.

[Insert figure 1]

Regatta Race Characteristics

Table 1 reports the race time, distance and average board speed across the 94 regatta races included. There was a large range experienced for total race time with longest race ~ 21 and 13 min longer than the shortest for Men and Women, respectively. Race distance varied greatly, with the race distance covered ~ 5.4 x greater in Men and 4.5 x greater in Women from the longest race compared to the shortest. Average speed of competitors also varied greatly, with Men ranging from 3.66 (1.88 m.s^{-1}) to 16.78 (8.63 m.s^{-1}) knots and Women from 3.32 (1.71 m.s^{-1}) to 14.68 (7.55 m.s^{-1}) knots.

[Insert table 1 here]

Men's Race Characteristics

There was a main effect of race wind category on race time ($F_{4,42}$ = 4.707; P = 0.003), with light to medium races longer than medium (P = 0.006), medium to heavy (P = 0.014) and heavy (P = 0.46) but not light (P = 0.559). There was a main effect of race wind category on race distance ($F_{4,42}$ = 24.875; P < 0.001), with light wind races shorter than medium (P = 0.001), medium to heavy (P < 0.001) and heavy (P < 0.001) but not light to medium (P = 0.149). There was a main effect of race wind category on competitor race speed ($F_{4,42}$ = 43.464; P < 0.001), with light wind races slower than medium (P < 0.001), medium to heavy (P < 0.001) and heavy (P < 0.001) but not light to medium (P = 0.579). A summary of these data are presented in Table 2.

Women's Race Characteristics

There was no main effect of race wind category on race finishing time ($F_{4,40}$ = 2.085; P = 0.101). There was however, a significant main effect of race wind category on race distance ($F_{4,40}$ = 36.463; P < 0.001), with light wind races longer than medium (P < 0.001), medium to heavy (P < 0.001) and heavy (P < 0.001) but not medium to light (P = 1.000). There was a main effect of race wind category on competitor speed ($F_{4,40}$ = 47.982; P < 0.001), with light winds slower than medium (P < 0.001), medium to heavy (P < 0.001) and heavy (P < 0.001) but not medium to light (P = 1.000). A summary of these data are presented in Table 3.

[Insert table 2 here]

[Insert table 3 here]

Windward Mark Rounding Positions

Mean WWM rounding positions for Men and Women were similar for competitors who finished 1st (2.2 ± 2.1 vs. 2.2 ± 1.9), 2nd (3.7 ± 2.6 vs. 3.4 ± 2.2) and 3rd (5.0 ± 3.3 vs. 4.0 ± 2.8) and increased as competitors finished lower on the podium. The range of the WWM rounding

increased between positions 1st, 2nd and 3rd for men (1st = 8, 2nd = 12 & 3rd = 14) and increased only between 2nd and 3rd for Women (1st = 9, 2nd = 8 & 3rd = 12).

[Insert table 4 here]

In light and light to medium wind races (n = 17) the mean WWM rounding position for Men was 2.1 ± 1.7, 3.6 ± 2.2 and 4.5 ± 2.9 for 1st, 2nd and 3rd, respectively. For Women, the mean WWM rounding positions in light and light to medium wind races (n = 18) was 2.3 ± 2.2, 3.1 ± 1.7 and 4.2 ± 2.7 for 1st, 2nd and 3rd, respectively.

1st upwind leg characteristics in light winds

Summary of data in Table 4. On average, Women's 1st leg was 17s longer in duration than Men. Both the distance covered and average speed was greater for Men than Women. A similar number of manoeuvres was completed between Men and Women over the 1st upwind leg (2.7 ± 1.3 vs. 3.1 ± 1.0).

[Insert table 5 here]

Discussion

The purpose of this study was to use the available GPS data from the 2017-2018 RS:X regatta season to describe the distribution in wind speeds and the associated race times, distances and speeds. Furthermore, the study aimed to understand the importance of the 1st upwind leg on race outcome through the analysis of WWM rounding positions. Specifically in pumping conditions, further characteristics were described of competitors achieving high (top five) WWM rounding positions.

Environmental conditions (i.e. wind speed, sea state and tide) often dictate the physical demands of a race and resulting in a profound influence on the outcome of a race (Castagna & Brisswalter, 2007; Chamari et al. 2003). Sailors are therefore required to possess the necessary

technical, tactical and physical characteristics to meet such demands (Bojsen-Møller et al. 2014). Perhaps unsurprising, data from the present study highlighted a large variation in wind speeds experienced by windsurfers during competition. However, it reinforces to both coaches and sport scientists the need to focus on developing a wide range of attributes that allow windsurfers to be competitive across a wide range of wind conditions to consistently perform at the highest level.

Women's race times across the different wind categories were not significantly different. Furthermore, for both Men and Women, as wind speed increased so did the race distance. The process of which course lengths are adjusted by race officials using pre-determined charts may partially explain the results. These charts take into the consideration the upwind, downwind and reach speed of a windsurfer for different wind speeds. Furthermore officials have the ability to alter (shorten or lengthen) if there is a dramatic change in wind speed during a race in the effort to maintain consistent total race time. Further evidence of these considerations is highlighted as race distance for Men was greater than Women for the respective wind categories due to race officials accounting for the greater speed Men are expected to travel due to a larger sail area (9.5 m^2 vs. 8.5 m^2).

The data highlighted the potential for high physical demands to be placed upon windsurfers during competition, especially in light winds with race times of ~23 min and ~24 min for Men and Women respectively. As previously referenced, pumping is most effective in light wind speeds both upwind and downwind (Castagna et al. 2008; Castagna et al. 2007) and considered the most physiologically demanding wind condition for windsurfers (Vogiatzis et al. 2002). Castagna et al. (2007) replicated four on-water sessions in two wind conditions. Specifically in the light wind session ($2 - 4$ ms^{-1} = $4 - 8$ knots) upwind pumping resulted in windsurfers achieving ~ 89 % of HRmax and ~ 83 % of $\dot{V}O_{2\,max}$. Downwind, these values were significantly higher, with ~ 93 % and 87 % of HRmax and $\dot{V}O_{2\,max}$, respectively. Thus it seems in light wind

races, windsurfers are required to maintain approximately 90 % of HRmax and 85 % of $\dot{V}O_2$ max for large proportions of races lasting in excess of 20 min. Such information could aid the formulation of tactical pacing strategies or recovery strategies that are require to manage races of these durations. Furthermore it provides key information to coaches and sport scientists to improve the effectiveness of specific training programmes (Caimmi & Semprini, 2017). With windsurfers regularly compete in two to three races per day for the duration of the regatta that typically lasts for five to six days; it is perhaps unsurprising that this repeated extended duration aerobic exercise means that windsurfers possess $\dot{V}O_{2\ max}$ values of 65 ml.kg.min^{-1} (Castagna et al. 2008), similar to other well-trained athletes in long distance events (Fiskerstrand & Seiler, 2004).

Competition related statistics are often used to determine the difference between winning and losing (Allister, Byrne, Nulty & Jordan, 2018). The data from the present study confirmed preliminary findings that a high 1st WWM position was important in achieving a podium finish for a race. Especially for those competitors who eventually won the race, where WWM positions were extremely high (Men = 2.2 ± 2.1 & Women = 2.2 ± 1.9). This is particularly meaningful as on average 34 Men and 28 Women competed in the World Sailing World Cup regattas. For the World Championships 85 Men and 62 Women competed, with races split into two fleets. A low 1st WWM position would allow a windsurfer to control the rest of the race and implement their chosen strategy and tactics with minimal interference from other competitors (Fajen, Riley & Turvey, 2008; Passos, Araújo, Davids & Shuttleworth, 2008). Thus, it would be of worthwhile consideration for coaches and support staff to invest time and resource in understanding how to profile, monitor and train a windsurfer's ability to achieve a high WWM position after the 1st upwind leg (Pluijms, Cañal-Bruland, Hoozemans & Savelsbergh, 2015).

Furthermore, the specific characteristics provided for the 1st upwind leg in pumping conditions could enhance the ecological validity if incorporated into specific laboratory-based testing (Currell & Jeukendrup, 2008). For example, time trial durations aligned with the time take for those finishing in high (Top three) WWM positions for both Men (7 min 31 s) and Women (7 min 48 s). However, caution should be taken in a single fixed duration time trial due to the large range in time experienced during the 1st upwind leg (~ 3 to 4 min difference between shortest and longest). Consideration of multiple fixed duration trials relevant to the 1st upwind leg might be more beneficial. This would also allow for a power-duration relationship to be derived. This method would provide theoretical means of predicting power output for specific time periods (Skiba, Chidnok, Vanhatalo & Jones, 2012) and allow for the performance of a windsurfer to be examined across a range of durations applicable to competitive performance. Furthermore, the power-duration relationship is considered most relevant for activities lasting ~ 2 to 30 min (Vanhatalo, Jones & Burnley, 2011), which is representative of durations presented in the study for both race and 1st upwind leg durations.

Practical implications and conclusions

This is the first study to analyse the GPS data available from Olympic windsurfing competition. The results indicate that competition race characteristics are highly varied and competitors subjected to a wide range of conditions resulting in different physical demands. Furthermore, podium finishes in races related to high WWM rounding positions, highlighting the potential importance of this race component. Finally, the 1st upwind leg characteristics provides coaches and sport scientists with information to enhance ecological validity of laboratory-based testing. Future studies focussing on the inclusion of internal data (i.e. heart rate) alongside the GPS in competition would provide a greater understanding of the physical demands experienced in competition.

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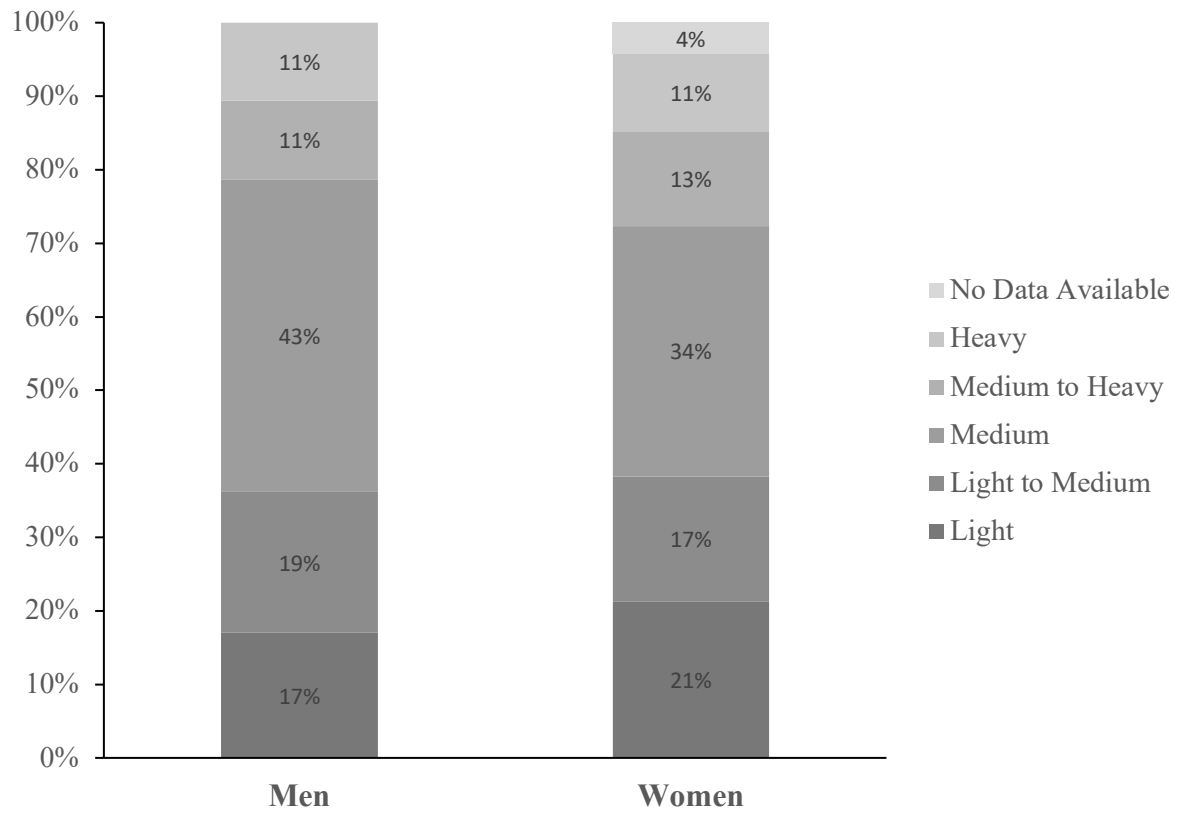
Figure 1. Distribution (%) of wind speed categories for both the 47 Men's and Women's

races analysed.

Table 1. Summary statistics of examined GPS variables for the 47 races for both Men and Women for competitors that finished in the top three.

	Min-Max		Mean ± SD		90% CI for the mean	
	Men	Women	Men	Women	Men	Women
Race Time (s)	825 – 2105	1036 – 1817	1281 ± 212	1308 ± 183	1229 – 1333	1263 – 1352
Race Distance (m)	2170 – 11786	2167 – 9844	6799 ± 2690	5351 ± 2525	6140 – 7457	4733 – 5969
Race Speed (kts)	3.66 – 16.78	3.32 – 14.68	10.61 ± 4.59	8.18 ± 4.20	9.48 – 11.73	7.15 – 9.21

CI = Confidence interval.

Table 2. Race time (s), distance (m) and speed (kts) of the top three finishers for different wind speed categories for the 47 Men's races

	Race Time (s)			Race Distance (m)			Race Speed (kts)		
	Min-Max	Mean ± SD	90% CI for the mean	Min-Max	Mean ± SD	90% CI for the mean	Min-Max	Mean ± SD	90% CI for the mean
Light *(n = 8)*	1151 – 1596	1322 ± 139	1229 – 1415	2170 – 4058	3132 ± 502	2170 – 4058	3.66 – 6.06	4.60 ± 0.61	4.06 – 5.14
Light to Medium *(n =9)*	1146 – 2105	1498 ± 271	1330 – 1666	3250 – 7438	5025 ± 1386	4166 – 5884	4.24 – 9.44	6.61 ± 1.75	5.53 – 7.69
Medium *(n = 20)*	825 – 1473	1222 ± 178	1153 – 1291	3726 – 11785	7607 ± 1995	6836 – 8379	7.03 – 16.30	12.04 ± 2.89	10.92 – 13.16
Medium to Heavy *(n = 5)*	1065 – 1308	1147 ± 102	1065 - 1308	8826 - 10443	9571 ± 692	8826 – 10443	15.52 – 16.78	16.23 ± 0.49	15.77 – 16.70
Heavy *(n = 5)*	1033 – 1308	1191 ± 117	1079 – 1303	8718 – 10652	9851 ± 910	8984 – 10719	15.52 – 16.78	16.08 ± 0.24	15.85 – 16.32

CI = Confidence interval. * Denotes significant difference to the light wind category, ** Denotes significant difference to the light to medium wind category

Table 3. Race time (s), distance (m) and speed (kts) of the top three finishers for different wind speed categories for the 45

Women's races

	Race Time (s)			Race Distance (m)			Race Speed (kts)		
	Min-Max	Mean ± SD	90% CI for the mean	Min-Max	Mean ± SD	90% CI for the mean	Min-Max	Mean ± SD	90% CI for the mean
Light *(n = 10)*	1248 – 1777	1435 ± 174	1335 – 1536	2449 – 3385	2900 ± 318	2716 – 3084	3.32 – 4.87	3.96 ± 0.48	3.68 – 4.24
Light to Medium *(n = 8)*	1100 – 1488	1299 ± 120	1219 – 1379	2167 – 4409	3443 ± 870	2860 – 4025	3.82 – 6.33	5.10 ± 0.99	4.44 – 5.77
Medium *(n = 16)*	1036 – 1817	1314 ± 224	1216 – 1413	2793 – 8827	5273 ± 1851	4461 – 6084	4.93 – 13.58	7.89 ± 2.91	6.61 – 9.17
Medium to Heavy *(n = 6)*	1038 – 1368	1210 ± 136	1098 - 1321	7513 – 9844	8792 ± 956	8006 – 9578	13.95 – 14.37	14.13 ± 0.16	14.00 ± 14.26
Heavy *(n = 5)*	1169 – 1302	1223 ± 51	1174 – 1272	8720 – 9320	9022 ± 263	8771 – 9272	13.73 – 14.68	14.34 ± 0.39	13.97 – 14.71

CI = Confidence interval. * Denotes significant difference to the light wind category

Table 4. WWM rounding position for competitors finishing either 1st, 2nd or 3rd for Men and Women.

	1st			2nd			3rd		
	Min-Max	Mean ± SD	90% CI for the mean	Min-Max	Mean ± SD	90% CI for the mean	Min-Max	Mean ± SD	90% CI for the mean
Men $n = 47$	1.0 – 9.0	2.2 ± 2.1	1.7 – 2.7	1.0 – 13.0	3.7 ± 2.6	3.1 – 4.4	1.0 – 15.0	5.0 ± 3.3	4.2 – 5.8
Women $n = 47$	1.0 – 10.0	2.2 ± 1.9	1.8 – 2.7	1.0 – 9.0	3.5 ± 2.2	2.9 – 4.0	1.0 – 13.0	4.0 ± 2.8	3.3 - 4.7

CI = Confidence interval

Table 5. Average 1st upwind leg duration, distance, speed and number of manoeuvres for the competitors rounding in the top three positions at the WWM for both Men and Women in light and light to medium races.

	Time (s)			Distance (m)			Speed (kts)			Number of Manoeuvres		
	Min-Max	Mean ± SD	90% CI for the mean	Min-Max	Mean ± SD	90% CI for the mean	Min-Max	Mean ± SD	90% CI for the mean	Min-Max	Mean ± SD	90% CI for the mean
Men **(n = 17)**	361 – 562	451 ± 54	428 – 473	719 – 2547	1207 ± 473	1007 – 1407	3.38 – 9.41	5.14 ± 1.61	4.46 – 5.82	1.0 – 6.0	2.7 ± 1.3	2.2 – 3.3
Women **(n = 18)**	364 – 633	468 ± 68	440 – 496	737 – 1173	942 ± 135	887 – 998	3.12 – 5.67	3.98 ± 0.77	3.57 – 4.30	1.3 – 5.0	3.1 ± 1.0	2.7 – 3.6

CI = Confidence interval.