Received: 9 February 2022 | Revised: 29 August 2022 | Accepted: 8 November 2022

DOI: 10.1111/sms.14273

ORIGINAL ARTICLE

WILEY

Handling shifts during an overnight sailing regatta: Comparison between sleep management strategies

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Funding information
ARPA foundation; Italian Ministry of Health

The study aims to investigate the association between different sleep management strategies and the final ranking during a one-night sailing race. A large sample of 190 teams participating in the overnight sailing regatta (151 Miglia) were included in the study. The experimental design consisted of two surveys, administered one before the start of the race and the other after the arrival. The questionnaires provided general information on the sailboat, its crew, and the strategy adopted to manage sleep during the race. In this one-night regatta, the self-management of sleep/wake timing emerged as the most successful strategy. Among participants who adopted a shift-based racing strategy, a short night shift duration (i.e., 2 h) significantly predicted a better placement. These findings confirmed the relevance of sleep management in sport performance and provided new insights into the most suitable sleep management strategy during a relatively short offshore regatta. The conclusions might apply also to similar continuous-cycle activities. Further investigations are needed to explore best sleep management strategy in team regattas of longer duration.

KEYWORDS
endurance, night shifts, sailing, sleep management, sport performance

1 | INTRODUCTION

The growing interest in the regulatory mechanisms behind sleep is due to the many functions it fulfills, ranging from improving neurocognitive processes to restore physical health.[1] Therefore, a good sleep management is crucial in the regulation of activities requiring a combination of mental and physical preparation, like those necessary in endurance sports.[2] Many authors claimed the attention on the psychological dimension involved in the perception of fatigue. Fatigue can be defined as "the physical and/or mental weariness resulting from exertion, that is, an inability to continue exercise with the same intensity without a resultant deterioration in performance."[3] Therefore, fatigue applies not only to the muscular effort but also to athletes' psychology. Sleep loss exerts a negative effect on perceived effort values[4] and on cognitive and neurobehavioral performance,[5,6] resulting in a reduction in the ability to encode new information and consolidate memory.[7] Sleep loss consists of insufficient sleep continuity and/or duration. It can be both acute or chronic, as the result of either exogenous (e.g., shift work) or endogenous causes

Section specialty area: Section V: Psychology of Sport, Exercise and Health.

(e.g., engaging in endurance activities).[8] Among cognitive functions, sustained attention is a fundamental prerequisite for a high-level performance during any complex task[9] and is detrimentally affected by sleep loss.[10] Similarly, more complex cognitive functions are deeply influenced by sleep, as it occurs for decision-making.[11] The effects of sleep loss on decision-making may emerge as a change in individual behavioral patterns, for instance showing a higher propensity to take risks.[12] On top of the cognitive impairments associated with sleep loss, several lines of research have highlighted the importance of sleep in the physiological regulation of emotions and mood.[13]

With respect to endurance sports, Roberts and co-workers demonstrated that a three-day sleep restriction slowed down the performance of cyclists/triathletes, also reducing their psychomotor vigilance and increasing their mood disturbances.[14] In another sample of triathletes, precompetition total sleep time has been significantly associated with the performance on the subsequent day, explaining approximately one third of the outcome variance.[15] In endurance athletes, a sleep duration of less than 7 h per night was significantly associated with new injury risk, highlighting how an optimal sleep management might improve their safety and not only performance.[16] An inefficient sleep management, conversely, can result in life-threatening mistakes when sports are performed under challenging conditions.[17] Military members may also experience severe sleep loss as a part of their job requirements. In this population too, insufficient sleep has been associated with reduced aerobic capacity, muscular endurance and performance in military-specific tasks[18] extending beyond sport science the importance of an optimal sleep management when facing high physical and cognitive loads.

Sailing races are continuous-cycle team sports requiring a continuous attention span. The crews of offshore boats are subject to a very high daily energy expenditure, also related to the difficulty (when not impossibility) to relax during the day and night.[19] During a multiday racing significant functional changes caused by sleep loss (e.g., mood changes and attention decline) can occur, possibly leading to technical errors.[2] Growing levels of fatigue, circadian misalignment, and cognitive workload can become critical issues for the performance and safety of sailors.[20] Therefore, it is essential to find an optimal balance between waking and sleep to achieve a competitive advantage and prevent injuries.[21] The applied research to sport performance and sleep management brings expertise and methodologies to equip the athletes with adequate tools to manage their sleeping hours.

This discipline offered the first attempts to evaluate the potential risks coming from sleep loss with a study conducted by Stampi in 1989. He enrolled 99 sailors participating in three double or solo regattas. Stampi discovered that the best performance was obtained by those sailors who slept for multiple time slots ranging from 20 min to 1 h, and for a total of 4.5–5.5 h of sleep per day. All the participants completed a questionnaire on sleep quality and were interviewed before and after the regattas to assess their sleeping habits, the presence of any sleep disorders, the sleep strategy planned for the regatta, as well as the schedule actually adopted. In addition, each sailor had to fill a sleep diary and was asked to report, when possible, the exact sleep onset and offset time for each sleep episode during the race; alternatively, they were asked to fill in a short daily report estimating the average, minimum and maximum duration of each episode and the total sleep time across the 24 h.[22]

Since Stampi's seminal paper, a few more studies were conducted on sleep management during sailing races, mainly focusing on double or solo regattas. Hurdiel and colleagues[2] described the sleep patterns and functional impairments of 16 sailors during a solo transatlantic race. Participants followed a polyphasic sleep-wake cycles which showed a physiological circadian pattern, i.e., sleep propensity was higher during the night. Sleep duration was drastically reduced to about 4–5 h per day. Functional impairments reported by participants (technical errors, mood changes, hallucinations) are compatible with the effects described in controlled laboratory settings caused by chronic sleep restriction paradigms (i.e., the critical curtailment of time in bed, and therefore sleep duration, for multiple consecutive nights). The same research group also demonstrated that 12 sailors performing one- and two-day single-handed regattas faced a severe sleep insufficiency, significantly impairing their cognitive performance.[20] Galvani et al.[19] also reported a polyphasic sleep-wake pattern in four teams participating in a double-handed 500 miles regatta. Participants slept, on average, five times a day, and each sleep episode lasted about 36 minutes. Léger and co-workers' results[23] highlighted the impact on the final ranking of the sleep debt accumulated by crew members in the days preceding the competition. A greater sleep debt was associated with an increased total sleep time on board and a worse ranking. Getting a sufficient sleep amount before the race turned out to be a winning strategy.

Although previous studies conducted on sleep during sailing consistently highlighted the importance of a careful management of crew sleeping hours, it is still not clear how the time devoted to sleep should be handled in order to achieve the best final placement. With the objective of providing practical and easy-to-implement hints to ship-owners and crew members, we conducted, to the best of our knowledge, the first study investigating the best sleep-wake cycle management strategy during a team sailing race, taking advantage of a large flotilla. We explored whether following a predefined sleep management scheme during the competition was associated with a better performance, and in that case, which is the most effective among the adopted strategies. More specifically, we hypothesized that very short night shifts would be significantly associated with a better final ranking, consistently with previous studies conducted on double/solo regattas. Indeed, short shifts allow sailors to obtain multiple brief sleep episodes, a sleep pattern that has been associated to the best performance.[22]

2 | METHODS

2.1 | Study setting and population

The study was conducted during the 10th edition of the "151 Miglia-Trofeo Cetilar®" sailing race (2019), one of the most participated events of the Italian Offshore Championship. The only requirements for the participation in the regatta include Italian Sailing Federation (FIV) membership and medical certification (for Italian crew members and a waiver for sailors resident in other countries). These requirements may be fulfilled by a wide range of athletes, from professionals to "Sunday sailors." The heterogeneity of the boats participating in this race, as well as the different level of expertise of the sailors, offered a unique variety of possible sleep management strategies adopted. The average duration of the race is relatively short, ranging from 12–45 h over a course 151 nautical miles long. All the 251 shipowners regularly registered were invited to participate in the study. Overall, 190 teams contributed to data collection. Their vessels might belong to the International Rating Certificate (IRC), Offshore Racing Congress (ORC) and OVER 60 categories.

All shipowners signed an informed consent before taking part in the study. The study was conducted in accordance with the Declaration of Helsinki and has been approved by the Bioethical Committee of the University of Pisa on May 5th, 2009, with protocol number 0048623/2019.

2.2 | Study design and measures

Two ad hoc questionnaires, inspired by the work of Stampi,[22] were administered to the shipowners who agreed to participate in the study. The first (Q-pre) consisted of 24 multiple-choice questions and collected basic information about the shipowner, the members of the crew, and the sleep management strategy they planned. The second (Q-post) questionnaire consisted of 22 multiple-choice questions identical to the Q-pre. Only two questions have not been re-proposed because they relate to past experiences and not to the strategies adopted in the regatta under consideration. Both the questionnaires were branched, so that participants answered to a different set of questions according to the declared sleep management strategy. In particular, only teams who declared having followed a predefined shift schedule were asked to specify shift schedule characteristics, such as shift duration and shift pattern. When comparing the answers provided to Q-pre and Q-post, some inconsistencies emerged. All analyses were hence performed on data collected through the Q-post questionnaire, since they were more likely to reflect the actual strategy adopted during the competition. Only one participant in Q-post answered that the bowman was in charge of defining the sleep management strategy. Due to the impossibility of performing comparisons against a group consisting of only one observation, this participant has been excluded from the analysis. The English translation of the complete version of both questionnaires is provided in the Appendix (Appendix S1).

The collected data included information on:

- The number of crew members;
- The adoption of a predefined shift schedule;
- Who was in charge of defining the sleep management strategy;
- The type of shift pattern: participants could choose among three options the most similar to the shift pattern they actually adopted:
  - ON/OFF, that is, crew members are divided into two groups: one active, the other resting;
  - ON/OFF/Stand-by, that is, crew members are divided into three groups: one active, one resting, one not active but available in case of need;
  - Partially overlapped, that is, crew members in charge during the previous shift remain active for a small period during the new shift, so that there is no complete disconnection between the groups.

For each type of shift, we also asked participants to specify the relative duration.

- Differences in night/day shift duration;
- Onset and end time of the night shift schedule;
- The duration of a night shift: this information was directly acquired from participants who declared a difference in the duration of night and daily shifts; if participants declared no difference in the duration of night shifts and daily shifts, night shift duration was assumed to be identical to daily shift duration. Reported night shift duration higher than or equal to 8 h were excluded, since this time window roughly coincides with the whole night and performing a night shift of the duration of the whole night coincides with not performing shifts.

The final ranking was used as a direct measure of sport performance. The official ranking of the "151 Miglia-Trofeo Cetilar®" was established by using the compensated times, a handicap correction commonly applied to heterogenous regattas, that takes into account specifications of the boats (e.g., hull length, sail area or weight) and not only the time in which sailing teams actually finished the race. The use of a rating system may alleviate disparities in victory chances based on boat characteristics. Both Offshore Racing Congress (ORC) and International Rating Certificate (IRC) compensation ratings were used in this paper.

2.3 | Statistical methods

Statistical analyses were performed using the R Software version 4.0.4. For quantitative variables, mean and standard deviation were reported, with exception for the number of the crew members. Indeed, expressing the average number of crew member using non-integer values (as the mean and the standard deviation of our sample distribution are) might be misleading. Therefore, we preferred to report the median and the interquartile range of the number of crew members of the participating teams. Frequencies and percentages were used to describe categorical variables. ANOVA was used to test possible associations between the final placement and sleep management-related variables; eta squared (η^2) was used to quantify the strength of those associations. Pearson correlation test was used to explore a possible association between the number of crew members and the final ranking. Linear regression models were estimated to identify possible predictors of the final ranking, both in the whole sample and among participants who adopted a predefined shift schedule. All statistical tests were two-sided, and the level of significance was set at 0.05.

3 | RESULTS

Of the 190 recruited teams, 102 filled Q-pre, 168 filled Q-post, 80 completed both questionnaires. Descriptive statistics are reported in Table 1.

Some inconsistencies emerged comparing the answers given by participants who filled both Q-pre and Q-post. Only 51 teams out of 80 (63.8%) actually performed the competition with the planned number of crew members. Twenty teams (25%), instead, sailed with about two crew members less than originally declared, whereas nine teams (11.2%) eventually sailed, on average, with one additional crew member. We obtained similar results comparing Q-pre vs Q-post information regarding shift management. In fact, only around two thirds of participants adopted the shift schedule planned before the race.The associations between the final ranking and sleep management-related variables are reported in Table 2.

The number of crew members, ranging from 2 to 20 (median = 8), significantly and negatively correlates with the final ranking. Moreover, differentiating daily and nightly shift pattern and a short night shift duration were also associated with a better sailing performance (Figure 1).

No other variable was significantly associated with the outcome. According to standard criteria used to interpret η^2[24] and Pearson's correlation coefficient values,[25] all effect sizes are small.

We estimated a linear regression model considering the final ranking as dependent variable and following a predefined shift-based sleep management strategy as independent variable. The number of the crew members was also included as covariate, since it was significantly correlated with the final placement. The results showed that following a predefined shift schedule significantly predicted a worse placement, while a higher number of crew members significantly predicted a better final ranking (Table 3).

Second, to identify the best shift-based sleep management strategy, we estimated a linear regression model considering only the subsample of the teams who followed a predefined night shift pattern. We considered the final ranking as the dependent variable. The following predictor were included in the model: the number of crew members, who was in charge of defining the sleep management strategy (i.e., the shipowner, the whole crew, the skipper or the tactician), the shift pattern, an indicator of following different day/night shift patterns and the night shift duration. As described above, also in this model a higher number of crew members was significantly associated with a better placement. A shorter night shift duration significantly predicted a better final ranking. Results are fully displayed in Table 4.

4 | DISCUSSION

The aim of the present study was to assess the impact of different sleep management strategies on the final ranking during the one-night team sailing race "151 Miglia-Trofeo Cetilar®." The results confirmed the importance of an optimal sleep management in determining a good performance in continuous-cycle team sport such as sailing, providing at the same time useful insights on how to manage sleep in such a context. With respect to the overall sample, not adopting a predefined shift schedule emerged as the best strategy. Moreover,

TABLE 1 Descriptive statistic of the sample. Data collected both before (Q-pre) and after (Q-post) the competition are reported

	Q-pre (N = 102)	Q-post (N = 168)
Crew members		
	8 (6–10)	8 (6–10)
Vessel category		
IRC	21 (20.6%)	35 (20.8%)
ORC	75 (73.5%)	120 (71.4%)
OVER 60	6 (5.9%)	13 (7.8%)
Shift schedule		
Yes	92 (90.2%)	121 (72%)
No	10 (9.8%)	48 (28%)
In charge of sleep management		
Shipowner	42 (41.2%)	51 (30.4%)
Skipper	14 (13.7%)	19 (11.3%)
Tactician	14 (13.7%)	15 (8.9%)
All crew	20 (19.6%)	34 (20.2%)
Bowman	0 (0%)	1 (0.6%)
Role-based	2 (2%)	0 (0%)
Self-managed	9 (8.8%)	46 (27.4%)
All awake	1 (1%)	2 (1.2%)
Shift pattern	*n = 92*	*n = 121*
ON/OFF	39 (38.2%)	74 (61.2%)
ON/OFF/Stand-by	40 (43.5%)	34 (28.1%)
Partially overlapped	13 (42.4%)	13 (10.7%)
Different day/night shift pattern	*n = 92*	*n = 121*
Yes	52 (56.5%)	46 (38%)
No	40 (43.5%)	75 (62%)
Night shift duration (hours)	*n = 92*	*n = 121*
1	0 (0%)	1 (0.8%)
2	42 (45.6%)	54 (44.6%)
3	37 (40.2%)	49 (40.5%)
4	11 (12%)	15 (12.5%)
7	1 (1.1%)	0 (0%)
8	1 (1.1%)	1 (0.8%)
10	0 (0%)	1 (0.8%)

in the subpopulation of participants who adopted a precise shift schedule, reducing the duration of night shifts significantly predicted a better final ranking. Finally, irrespective of the shift schedule, a higher number of crew members significantly improved the overall performance (i.e., better final ranking placement). As the ranking fed in the model is compensated according to either the Offshore Racing Congress (ORC) or the International Rating Certificate (IRC) rating systems, the number of crew members is likely to be independent of the boat size in the association with the ranking.

A short night shift duration was significantly associated with a high ranking: according to our models, adopting a night shift duration of 2 h predicted the best ranking, while for each extra hour of shift duration, the final placement worsened by 15 positions on average. A possible interpretation is that a longer night shift duration would probably imply a longer time spent awake at night for crew members, thus increasing their homeostatic need for sleep.[26] The likelihood of occurring in an attentional lapse gradually increases along with the amount of time spent awake.[27] It is therefore possible that the more

TABLE 2 Associations between final ranking and different sleep management-related variables

	Final ranking	Effect size	*p* value
Number of crew members		−0.27	<0.001**
Shift schedule			
Yes	49.24 (32.91)	0.006	0.33
No	43.17 (37.53)		
In charge of sleep management			
Shipowner	50.25 (36.55)	0.06	0.06
Skipper	39.22 (37.29)		
Tactician	29.27 (34.41)		
All crew	59.26 (36.67)		
Self-managed	44.70 (32.74)		
Shift pattern			
ON/OFF	50.27 (37.11)	0.03	0.17
ON/OFF/Stand-by	41.12 (38.06)		
Partially overlapped	64.00 (36.13)		
Different day/night shift pattern			
Yes	39.09 (33.40)	0.04	0.02*
No	55.33 (38.75)		
Night shift duration			
2	39.33 (34.07)	0.04	0.002*
3	53.81 (38.76)		
4	71.67 (36.79)		

Note: Final ranking is reported as mean (standard deviation). Effect size is expressed by Pearson correlation coefficient (r) for number of crew members (quantitative variables), eta squared (η^2) otherwise (categorical variables). Significance codes: * < 0.05, ** < 0.001.

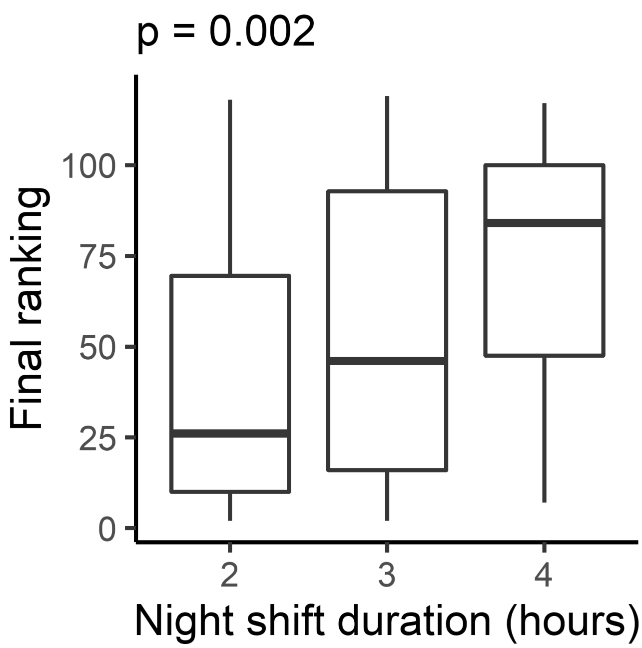

FIGURE 1 The boxplot illustrates the significant association ($p = 0.002$, ANOVA) between night shift duration (expressed in hours) and the final ranking placement. Teams who adopted the shortest night shift duration (i.e., 2 h) achieved the best positions, while longer durations were associated with a worse performance

frequent brief naps allowed by a short night shift duration would be sufficient to prevent sailors' attentional performance to excessively deteriorate, thus preventing them from committing technical mistakes. This hypothesis, and more generally our findings, are consistent with Stampi's results, which showed that the best sailing performance is achieved by sailors who divide sleep into very brief episodes of less than an hour.[22] This notion is now corroborated by a large sample of observations simultaneously collected during the same regatta. Further investigations will shed light on the relationship that links reduced night shift duration and improved sailing performance.

Not adopting a predefined shift schedule also emerged as a significant predictor of a better placement, on average by 13 positions. Among the teams who declared following no shift schedule, wake and sleep timing was mostly self-managed by each crew member (46 out of 48). A flexible shift pattern might have allowed a better fit between shift schedule and individual chronotypes. Investigating chronotypes might represent a further step in the attempt to develop the best shift handling strategy in endurance sports, as already in place in industrial settings. Moreover, a flexible management of shifts could have ensured more crew members to be quickly available in case of need, which represented an advantage against competitors. The significant association between a higher number of crew members and a better final placement showed by the current study might also support this hypothesis. In fact, each additional crew member significantly predicted an average improvement of four positions. However, the relatively short duration of the competition is to be considered as well. It is likely that longer regattas would highlight the importance of a carefully planned sleep management strategy to achieve a better performance and to handle fatigue. Further studies should evaluate the possibility to extend the validity of the proposed approach to longer sailing competitions and other team endurance sports, such as endurance motorsport.[28]

One important limitation of this study is the absence of objective data on sleep and sleep management. The use of actigraphy in sailing context could provide a reliable alternative to self-administered questionnaires.[29] Actigraphy, in fact, allows researchers to monitor participants' sleep/wake cycle for several days in a non-invasive and objective fashion that does not interfere with the execution of the athletic gesture and other ongoing activities. The use of actigraphy could also be useful in monitoring sailors' sleep in the days preceding the competition, providing

TABLE 3 Linear regression model testing the impact of the adoption of a predefined shift schedule and the number of crew members on the final ranking

	Estimate (95% Confidence interval)	Standard Error	*p* value
Intercept	67.47 (52.14/ 82.81)	7.77	<0.001**
Number of crew members	−3.58 (−5.31/−1.85)	0.87	<0.001**
Shift schedule			
No			
Yes	12.61 (0.50/24.72)	6.13	0.041*

Note: Significance codes: * < 0.05, ** < 0.001. Multiple R^2 = 0.10, Adjusted R^2 = 0.09. *N* = 168. In reporting the statistics of categorical regressors, blank rows represent the references for comparisons.

TABLE 4 Linear regression model exploring the best sleep management strategy in the subsample of teams who adopted a precise shift schedule. The final ranking represents the dependent variable

	Estimate (95% Confidence interval)	Standard error	*p* value
Intercept	57.50 (27.86/87.14)	14.95	<0.001**
Number of crew members	−4.89 (−7.13/−2.65)	1.13	<0.001**
Shift pattern			
ON/OFF			
ON/OFF/Stand-by	0.37 (−14.02/14.77)	7.26	0.96
Partially overlapped	−2.45 (−23.82/18.92)	10.78	0.82
In charge of sleep management			
Shipowner			
All crew	0.95 (−14.33/16.23)	7.71	0.90
Skipper	−4.10 (−22.95/14.75)	9.51	0.67
Tactician	−10.09 (−30.03/9.84)	10.06	0.32
Different day/night shift pattern			
No			
Yes	−8.49 (−21.65/4.66)	6.64	0.20
Night shift duration (hours)	14.73 (5.61/23.85)	4.60	0.002*

Note: Significance code: * < 0.05, ** < 0.001. Multiple R^2 = 0.28, Adjusted R^2 = 0.22. *N* = 118. In reporting the statistics of categorical regressors, blank rows represent the references for comparisons.

baseline data on chronotype and sleep debt. The amount of sleep debt accumulated by crew members before the competition, indeed, have been negatively associated with teams' performance.[23] Not having collected information about sleep management before the race should also be addressed as a limitation of the current study. Finally, the presence of a dedicated sleep area within the vessels might be considered as a potential confounder we did not take into account.

Despite the limitations inherent to this study, we might draw some tentative conclusions: during a one-night sailing race, letting each crew member have control over managing its sleep/wake cycle seemed to be emerged as the winning strategy. Among teams who adopted a precise shift schedule, a short night shift duration significantly predicted a better final placement. Independently of shift schedule, a higher number of crew members was significantly associated with a better sailing performance. These findings could help optimize sleep management during sailing races, although their generalizability should be tested during longer competitions. Different approach to research, for example, qualitative, would also bring a unique contribute to this field of investigation and should therefore be encouraged.

4.1 | Perspectives

To the best of our knowledge, this is the first study exploring the impact of sleep management during a team sailing race by comparing different strategies of a large fleet of competing crews. Our results are in line with background literature, which highlights the relevance of athletes' sleep optimization to achieve the best performance.[30] Moreover, they are in line with previous studies conducted in sailors, which show that very brief sleep episodes are associated with better ranking.[22] These findings can be translated into practical recommendations potentially useful to optimize sport performance, that is, keeping night shifts short and increasing the number of crew members. Moreover, sailing might not be the only field of application for our findings. There are many continuous-cycle systems (e.g., healthcare systems) where service provision must be continuously delivered, and where a decrease in performance leads to detrimental effects. Those activities could benefit from an optimal sleep management strategy, here described in a naturalistic controlled condition.

ACKNOWLEDGEMENTS

We would like to thank Federico Bianchi, Francy Cruz-Sanabria, Federico Cucchiara, Marco Di Galante, Eva Isoppo and Giuseppe Peretto for the support in data collection. We also thank the organizing committee, with a special acknowledgement to the YCRMP (Yacht Club "Repubblica Marinara di Pisa").

FUNDING INFORMATION

The present study was supported by Arpa Foundation (Sonnolab Grant to U.F.), by the Italian Ministry of Health Grant RC 1.21 and the 5 x 1000 voluntary contribution to IRCSS Stella Maris.

CONFLICT OF INTEREST

U.F. is co-founder and president of sleepActa S.r.l., a spin-off company of the University of Pisa operating in the field of sleep medicine. All other authors declare no competing interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Bruno S, Ceccanti S, Bazzani A, d'Ascanio P, Frumento P, Faraguna U. Handling shifts during an overnight sailing regatta: Comparison between sleep management strategies. *Scand J Med Sci Sports*. 2023;33:503-511. doi:10.1111/sms.14273