Accumulated Workload, Neuromuscular Fatigue, Wellbeing and Hormonal Variations in Professional Offshore Sailors: A Pre-competition Study

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ABSTRACT

This study aimed to comprehensively analyse the distribution of workload (WL) and its multifaceted impact on neuromuscular performance, wellbeing, and stress hormone levels within the professional offshore sailing context. Over a 27-week pre-competition period, ten professional sailors (8 males and 2 females) participated in regular assessments to evaluate their workload and its effects. Weekly workload (WL_{wk}), strain (WL_{str}), and monotony (WL_{mono}) were quantified using the session-rating of perceived exertion (sRPE), a validated tool for assessing training intensity. To measure subjective markers of recovery, the Hooper-index (HI) was collected weekly, providing insights into the athletes' perceived recovery status. Furthermore, salivary cortisol (C) levels, indicative of stress response, along with countermovement jump height (CMJ) and maximal strength on bench press (BP1RM), were assessed at the beginning of each training block to evaluate neuromuscular performance changes over time. Significant correlations were identified between the monitored workload indices and various variables. WL_{wk} showed associations with CMJ, BP1RM, HI, and C, indicating a relationship between workload and both physical performance and stress levels. WL_{mono} was correlated with HI, highlighting the impact of workload monotony on perceived recovery status. Similarly, WL_{str} was associated with CMJ, BP1RM, HI, and C, suggesting that workload strain affects neuromuscular performance, wellbeing, and stress hormone levels. In conclusion, the study suggests that integrating both objective (WL_{wk}, WL_{str}, WL_{mono}) and subjective (HI) monitoring tools can provide practitioners with valuable insights into optimising performance and managing stress in the demanding environment of offshore sailing.

Keywords: Monitoring; fatigue; adaptations; preparedness; performance; sailing.

INTRODUCTION

In the realm of sports science literature, the meticulous documentation of training and competition workload (WL) has garnered substantial attention. Over recent years, monitoring and managing WL have evolved as the gold standard for measuring the stress induced by physical activity with substantial research focusing on how training volume, frequency, and intensity influence non-functional overreaching, injury, and illness (16). However, a growing body of literature is now exploring the intricate relationships between WL, strain (WL_{str}), monotony (WL_{mono}), and data smoothing methods, and their combined effects on neuromuscular adaptations, hormonal balance, and overall sports performance (27).

Sailing is a multi-disciplinary and environmental dependent sport requiring sustained cognitive involvement for boat handling, navigation, and tactical skills combined with physically strenuous activities to manoeuvre the boat (30). Sailing, a sport that demands a unique blend of cognitive acuity and physical capacity, presents its own set of challenges. Previous research has documented the profound effects of sailing on neuromuscular functions, energy demands, and stress hormones, noting significant increases in neuromuscular fatigue, muscle damage, cognitive impairment, and elevated cortisol levels post-competition (12, 14, 15, 26, 31). Despite these findings, the literature remains sparse when it comes to understanding the physiological demands during the preparatory periods leading up to major competitions. Given the importance of recovery and stress management in achieving peak performance, there is a clear need to monitor both objective (internal and external) and subjective markers to comprehensively assess a sailor's readiness (39).

Cortisol, a key physiological marker of stress present in saliva, serum, and urine, provides valuable insights into the body's response to training loads, particularly when measured in saliva (19). Alongside cortisol, subjective assessments like the Hooper-Index (HI), which evaluates sleep quality, stress levels, fatigue, and muscle soreness, have shown promise in monitoring fatigue and recovery in team sports, suggesting potential applicability in sailing as well (28). Complementary field tests, such as the countermovement jump (CMJ) for neuromuscular fatigue and maximal strength tests, offer additional layers of insight into an athlete's physical condition, thereby supporting more effective training load management (7).

Despite significant advancements in understanding WL and performance in popular sports, the application of these principles to strategy-intensive sports like sailing remains underexplored. Sailing, particularly with the advent of modern hydro-foiling technology (4), demands not only sustained cognitive focus but also intense physical exertion, making WL management a complex challenge. As competitive sailing has evolved, so have the physical demands and injury risks faced by sailors (36). However, scientific literature on offshore sailing is notably sparse, partly due to the sport's variability and dependence on climatic and meteorological conditions. Implementing effective WL strategies in this ever-changing environment presents a substantial challenge for performance practitioners (13). However, performance in sailing is still linked to fitness (30) and, despite this precept, the relationship between variations in fitness levels and accumulated WL is not yet clearly established.

This study aims to address these gaps by first describing the WL distribution of a professional offshore sailing team participating in The Ocean Race (TOR) over a 6-month pre-competition period. Secondly, it seeks to identify dose-response predictors from periodically monitored indices using commonly employed WL variables. We hypothesise that these monitored indices will be directly influenced by WL, providing new insights into the complex interplay between workload and performance in professional sailing.

MATERIALS AND METHODS

Experimental Approach to the Problem

This study used a longitudinal prospective design to analyse the relationship between WL, neuromuscular performance, wellbeing, and salivary cortisol. All data was collected during the preparation of TOR 2021. The study was completed over a 27-week (W_{1-27}) pre-competition period. Figure 1 illustrates the training that was planned and scheduled by the skipper. Planning was adjusted to accommodate to weather conditions and Covid-19 crisis related restrictions. When sailing or training facilities were not available, sailors were prescribed training sessions by the strength and conditioning coach. On-land training included resistance training and metabolic conditioning (Figure 1B). All gym sessions were conducted in the Club Naval de Cascais (Portugal) or at home, when needed.

Together with WL variables, monitoring contained several subjective and objective markers of adaptation. Subjective markers included a wellness questionnaire for monitoring fatigue and were assessed weekly (Mondays). Objective markers included monitoring of strength and power

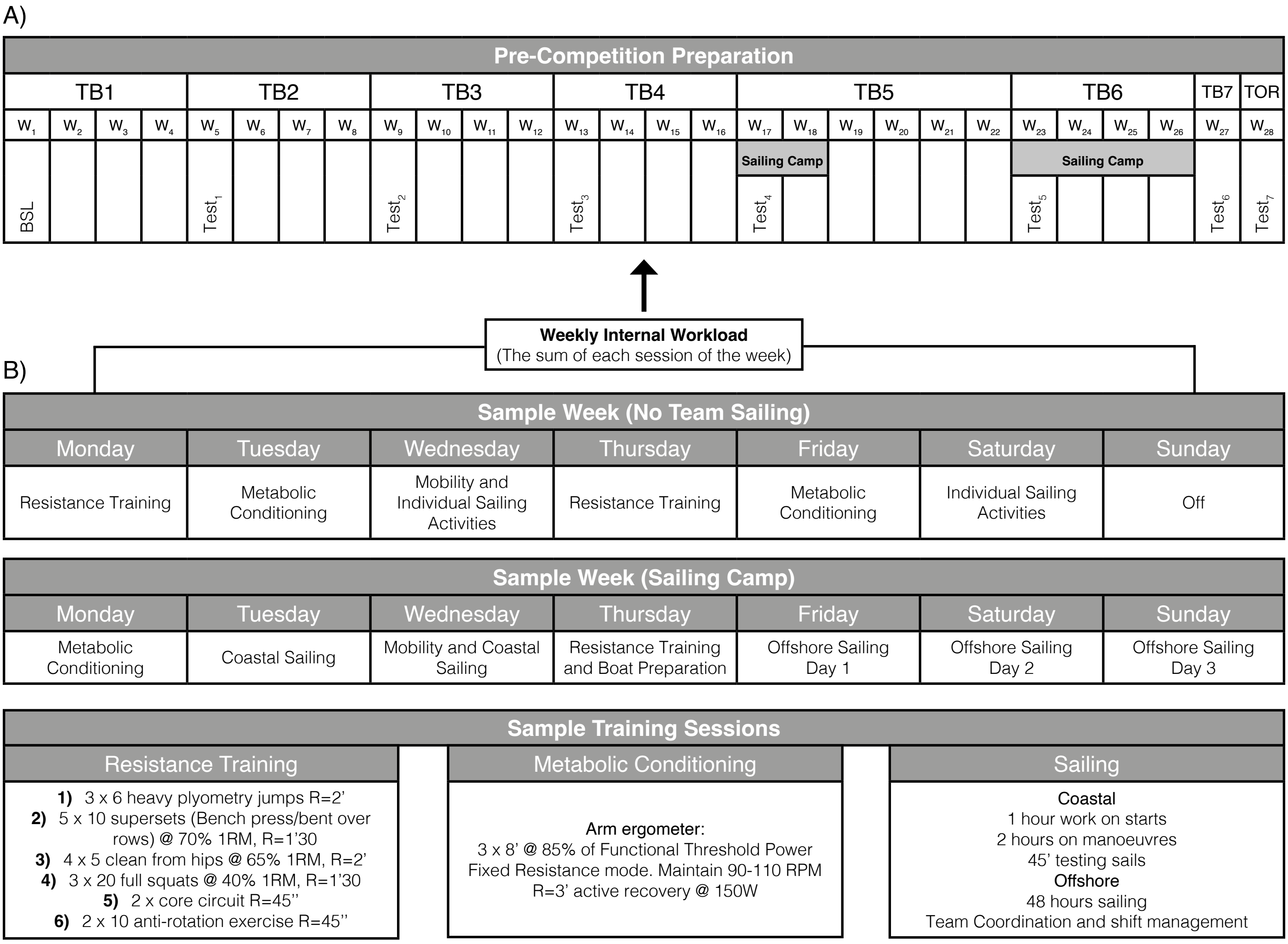

Figure 1. A) Schematic diagram showing the workload structure of the pre-competition blocks. The preparation was divided into seven distinct periods including two sailing camps. B) Organisation of sample weeks and training sessions. BSL: Baseline; TB_{1-7}: Training Block; W_{1-28}: Week; $Test_{1-7}$: Testing Battery; R: Rest; RPM: Revolutions Per Minute.

capabilities as well as hormonal biomarkers. These measurements were assessed on seven occasions ($Test_{1-7}$) which were held on the first day of each of the 7 training blocks (TB_{1-7}) (Figure 1A). $Test_{1-7}$ were conducted in the team's training facilities, located at the Club Naval de Cascais (Portugal), to ensure minimal disruption to the established sailing program. Athletes were requested to abstain from caffeinated drinks and alcohol 24 hours prior to testing. Data collection was made possible through a customised smartphone application (Appsheet). Athletes were permanently supervised by a qualified team doctor and nutritionist.

Subjects

The required sample size to conduct the study was estimated using statistical software (G*power; University 130 of Düsseldorf, Düsseldorf, Germany). The following variables were included in the a priori power analysis: study design, 1 group, 7 measurements, alpha error <0.05, nonsphericity correction = 1, correlation between repeated measures = 0.5, desired power (1-ß error) = 0.80, effect size of 0.5 based on a previous study that monitored self-reported wellness and CMJ performance in professional ruby union players over a 12-week period (17).

The results of the a priori power analysis indicated that a minimum of 6 participants was necessary to achieve statistical significance. The sample size computation took into account within-group variances and their correlations (*p*), thereby enhancing the methodological robustness and contributing to overall research integrity. Ten professional sailors (8 males and 2 females) from the same sailing team participated in the routine monitoring process (mean ± SD; age = 32.2 ± 3.96 years; stature = 179.1 ± 7.30 cm; body mass = 84.4 ± 11.8 kg). All participants were engaged in full-time training in preparation for TOR and were familiar with the assessments. None reported injuries or illnesses that would have impaired their physical performance in the six months preceding the monitoring. Although the data were collected as part of routine athlete monitoring procedures, and formal ethics committee approval was not required (40), the study adhered to the principles of the Declaration of Helsinki. All participants were informed about the purpose and procedures of the monitoring, and written informed consent was obtained. Data were anonymised before analysis to ensure confidentiality, and the sailing club granted permission for the data to be used for research and publication.

Procedures

Baseline Measures

On the first week of the pre-competition period, sailors underwent a medical screening battery. The testing battery occurred on Monday of the first week of the preparation phase and established the baseline (BSL) measurements. The protocol consisted of neuromuscular performance, wellbeing, and salivary cortisol testing. Sailors had not participated in high intensity training in the week prior to testing.

Workload Monitoring

WL was evaluated using session-rating of perceived exertion (sRPE) methods. Several variables were recorded: Weekly WL (WL_{wk}), strain (WL_{str}) and monotony (WL_{mono}). After each training session, sailors were requested to subjectively measure their physical exertion. RPE was recorded using the modified Borg 0 to 10 Scale (20). Athletes answered the question "How was your session?" within 30 min of finishing to maximise the accuracy of assessment of the full training session. sRPE was then measured by calculating RPE x the duration of the session (in minutes) (10). When offshore sailing data was collected for measurement, the time spent asleep, or resting was subtracted from the total sailing time. The following variables were then calculated: (i) WL_{week} as the sum of all WL during the week (Monday-Sunday); (ii) WL_{mono} as the mean of the WL during the seven days divided by the standard deviation of WL_{wk} and; (iii) WL_{str} as WL_{wk} multiplied by WL_{mono} (27).

Neuromuscular adaptations

Neuromuscular performance was evaluated using countermovement jump (CMJ) and bench press (BP) tests. Lower body power was tested on the CMJ using a Chronojump contact mat (Chronojump-Boscosystem™, Software, Spain). Each subject completed three attempts with 1 min of rest between trials. A countdown of "3, 2, 1, jump" was indicated orally before initiating the jump. All attempts were completed with subjects placing arms akimbo to avoid any parasitic movement. Athletes were instructed to perform a rapid eccentric phase, immediately followed by an explosive concentric contraction with the intention to jump as high as possible. The height of the best CMJ performance was reported for analysis. Markovic et al. (22) observed that CMJ, when measured by means of contact mat and a digital timer, is a valid and reliable field test for estimating muscle power of the lower limbs.

Maximal upper body pushing strength was assessed using the 1 repetition maximal (1RM) estimation based on Brzycki's equations (5). The estimation was calculated during training sets with less than 6-repetitions to avoid any risk of injury with the 1RM test. Bench press 1RM (BP_{1RM}) was not tested for $Test_7$ to avoid the delayed onset of muscle soreness before the start of TOR. Reliability of Brzycki's equation for measuring maximal strength on the BP1RM from a submaximal test has been validated by Amarante do Nascimento et al (2).

Wellbeing fluctuations

Wellbeing was assessed using the Hooper-Index (HI) with the recommendations of Hooper and Mackinnon (18). Athletes answered the questionnaire every Monday morning upon waking. Sleep quality, muscle soreness, stress and fatigue were scored on a 7-point scale where "1" and "7" represent "very, very good" and "very, very poor" respectively. The Hooper-Index was computed by summing its four subgroups (sleep quality, delayed onset muscle soreness, stress and fatigue). The reliability of using the HI for monitoring sports induced fatigue has previously been demonstrated (33).

Hormonal adaptations

Given the constraints of training schedules and logistical considerations, hormonal adaptations were evaluated by collecting salivary cortisol (C) samples upon waking (7:00 - 8:00am) acknowledging that this timing may introduce variability due to natural individual diurnal fluctuations in C levels (37). To ensure more rigorous testing and to limit cortisol measurement errors, athletes were required to refrain from eating, brushing their teeth and chewing gum prior to testing. Sailors placed the swab (Soma Bioscience, Wallingford, United Kingdom) on their tongue and closed their mouth. When the indicator on the swab's stem turned blue, the test was considered complete (swab collected 0.5 mL of oral fluid). The swab was then placed in the buffer bottle of assay (sodium phosphate, salts, detergents and preservatives) before gently mixing the sample for 2 min. Two drops of the sample were then placed in the window of the lateral flow device. The device was left still during the incubation period (10 min). The strip was then placed in the real-time reader and the results were ready within 20 s. C was then collected as nanograms per millilitre (ng/mL). Soma Bioscience oral fluid collector has been validated against enzyme linked immunosorbent assay (ELISA) and has been proven to be a reliable method to collect and analyse C (9).

Statistical Analyses

Over the 27-week study period, data from 148.12 ± 17.53 training sessions was collected and analysed. Data was calculated through standard statistical methods and is presented as mean ± standard deviation (SD). All variables were considered normally distributed through analysis with the Shapiro-Wilk test, histograms, and skewness values prior to analysis. One-way ANOVA with repeated measures was used to determine the differences between the different parameters measured at $Test_{1\text{-}7}$. The Pearson correlation coefficient (r) was used to assess the associations between WL variables and monitoring markers. Correlation coefficients were interpreted as: < 0.1 (trivial), from 0.1 to 0.3 (small), from 0.3 to 0.5 (moderate), from 0.5 to 0.7 (large), from 0.7 to 0.9 (very large), and ≥ 0.9 (nearly perfect) (6). The correlations were consistently presented with 95% confidence interval (CI). For all analyses, α was set at 0.05. Statistical analyses were performed using the SPSS package (15.0 version; SPSS, Inc., Chicago, IL, USA).

RESULTS

Figure 2A illustrates the weekly distribution of WL during the 27 analysed weeks of TOR pre-competition preparation. WL_{wk} variation displayed a high coefficient of variation (CV=1.18). Higher (p<0.001) WL_{wk} were observed during weeks of sailing camp (19792.6 ± 9428 AU; $W_{17\text{-}18}$ & $W_{23\text{-}26}$) compared to those not included in the camps (2813.2 ± 817.3 AU; $W_{1\text{-}16}$, $W_{19\text{-}22}$ & W_{27}). Higher WL were observed in the training blocks towards the end of the preparation schedule (Figure 2B). TB6 (22313 ± 6679.8 AU) confirmed higher WL (p<0.001) than TB_1 (2537.9 ± 289.1 AU), TB_2 (2555.3 ± 375.5 AU), TB_3 (2717.8 ± 642.5 AU), TB_4 (3236.3 ± 1074.7 AU), TB_5 (7652.3 ± 718.6 AU) and TB_7 (3116.3 ± 712.7 AU). TB5 was also significantly different (p<0.001) to all the other TB. TB_7, which was considered a taper week, showed lower (p<0.001) WL_{wk} when compared to TB_5 and TB_6 (Figure 2B). Repartition of WL during $TB_{1\text{-}7}$ is presented in Figure 3.

Within-group changes concerning CMJ, BP_{1RM}, HI and C, during the different phases of preparation, are provided in Table 1. CMJ and BP_{1RM} were significantly different (p≤0.05<p< p≤0.01) from BSL during $Test_1$, $Test_2$, $Test_3$, $Test_4$, $Test_5$, $Test_6$ and $Test_7$ respectively. HI (p=0.05) and C (p=0.05) were both significantly different from BSL only at $Test_6$.

The correlational analysis found multiple outcomes between WL variables and monitored markers. Large and very large positive correlations were found between WL_{wk} and BP_{1RM} (r=0.69, 95%, CI [0.11;0.92], p=0.02), HI (r=0.85, 95% CI [0.47;0.96], p<0.001) and C (r=0.84, 95% CI [0.44;0.96], p=0.001). Moderate negative correlations were also found between WL_{wk} and CMJ (r=-0.39, 95% CI [-0.81;0.31], p=0.05). WL_{mono} showed large positive correlations to the HI (r=0.55, 95% CI [-0.12;0.87], p=0.05). WL_{str} showed moderate negative correlations with CMJ (r=-0.48, 95% CI [-0.85;0.21], p=0.04) and large positive correlations with BP_{1RM} (r=0.52, 95%, CI [-0.16;0.87], p=0.05). WLstr also showed very large positive correlations with C (r=0.83, 95% CI [0.42;0.96], p=0.002) and very large positive correlations with the HI (r=0.88, 95% CI [0.56;0.97], p<0.001).

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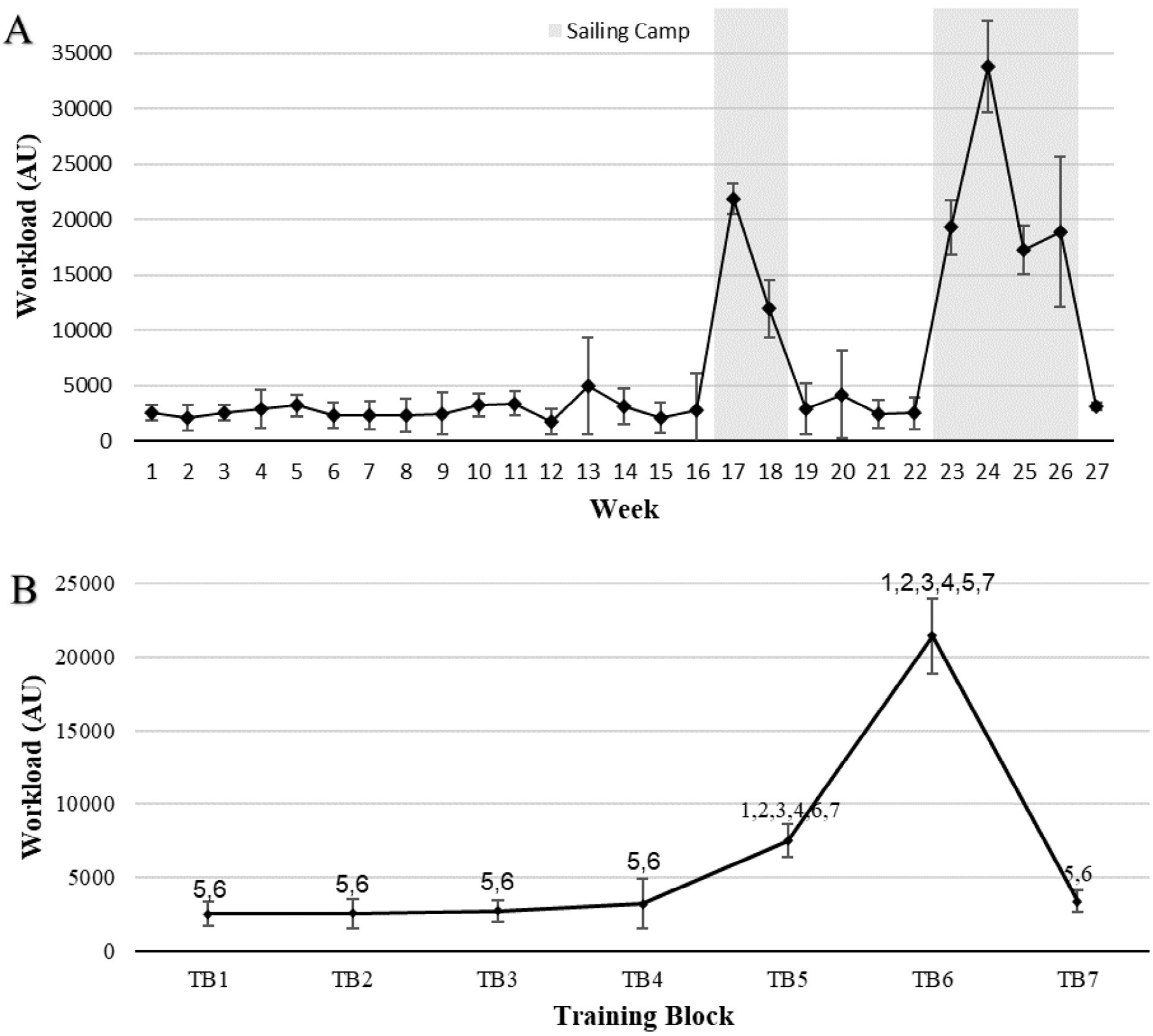

Figure 2. A) Weekly workload during the 27 weeks of preparation. Data are mean (± SD). B) Training block variations of weekly workload average. Data are mean (± SD). 1, 2, 3, 4, 5, 6 and 7: indicates to which TB it is significantly different ($p \leq 0.05$). AU: Arbitrary Units; TB_{1-7}: Training Block.

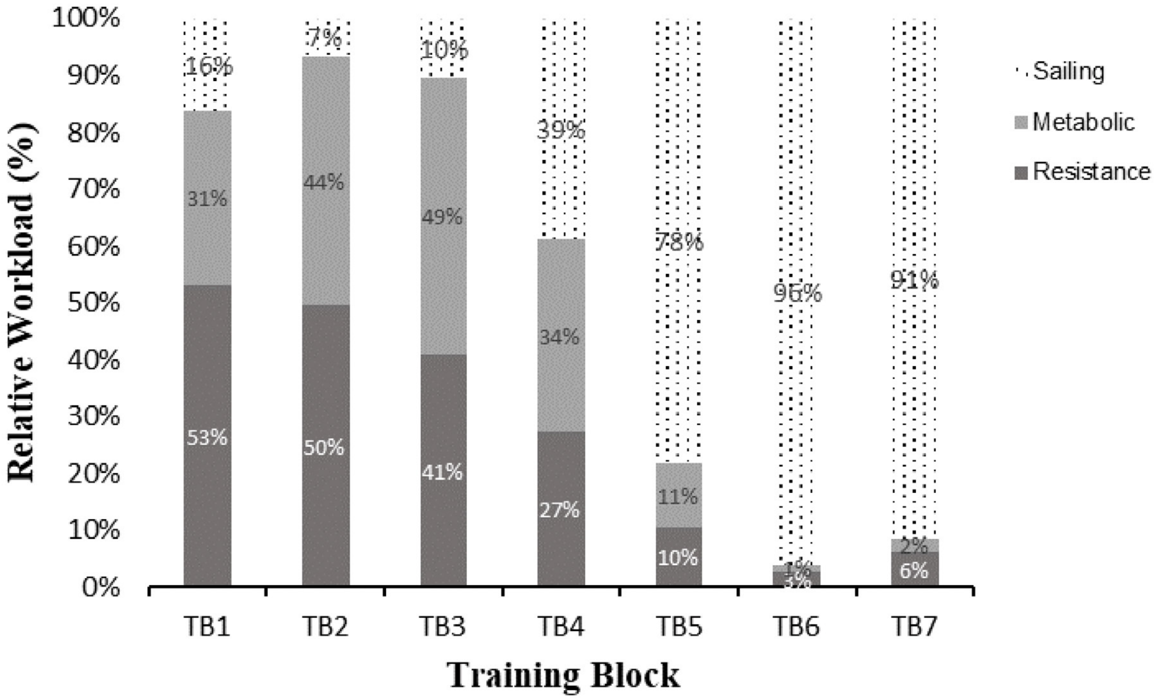

Figure 3. Repartition of workload specificity during each training block.

Table 1. Changes (mean ± SD) in monitoring markers throughout the preparation period.

	BSL	$Test_1$	$Test_2$	$Test_3$	$Test_4$	$Test_5$	$Test_6$	$Test_7$
CMJ (cm)	34.1±8.5	37.2±9.9*†	40.1±9.6**†	39.8±8.1**	42.6±7.5**†	43.0±8.1*	37.4±6.6*†	42.6±6.7**††
BP1RM (kg)	78.5±25.5	81.3±26.3*†	83.6±28.4*	84.8±27.9*	84.9±28.9*	88.6±30.3*	88.1±29.3*	
HI (AU)	13.2±3.3	13.7±2.2	14.8±2.1	12.2±2.3†	13.8±2.9	13.3±3.0	17.6±2.9*††	13.5±2.8††
C (ng/mL)	16.1±11.3	16.4±11.2	12.9±6.6††	16.3±7.2	8.8±3.9†	14.7±10.1††	25.4±9.8*††	12±4.6††

*BSL: Baseline; $Test_{1-7}$: Testing Battery; CMJ: Counter Movement Jump; BP1RM: Bench Press 1RM; HI: Hooper Index; C: Salivary Cortisol; * Significant difference with values of BSL; p≤0.05. ** Significant difference with value of BSL; p≤0.01; † Significant difference with values of preceding Test; p≤0.05. †† Significant difference with values of preceding Test; p≤0.01.*

[-0.12;0.87], *p*=0.05). WL_{str} showed moderate negative correlations with CMJ (*r*=-0.48, 95% CI [-0.85;0.21], *p*=0.04) and large positive correlations with BP_{1RM} (*r*=0.52, 95%, CI [-0.16;0.87], *p*=0.05). WL_{str} also showed very large positive correlations with C (*r*=0.83, 95% CI [0.42;0.96], *p*=0.002) and very large positive correlations with the HI (*r*=0.88, 95% CI [0.56;0.97], *p*<0.001).

DISCUSSION

The present study i) described the WL distribution during the pre-competition period of TOR and ii) aimed to identify the best dose-response predictors of periodically monitored indices with WL variables. The results indicate the significance of these assessments in monitoring neuromuscular performance, wellbeing, and physiological adaptations in professional offshore sailing. Indeed, the analysis showed correlations between WL parameters and the monitored indices. These findings offer practical insights for planning and programming interventions in professional crewed offshore sailing.

Despite extensive scientific interest in Olympic and America's Cup sailing (26, 38), the offshore sailing context remains relatively unexplored. To date, limited research concerning sailing WL and its' impact on neuromuscular performance, wellbeing and stress hormone levels has been documented (12, 18). This lack of literature may be explained, in part, by the complexity of conducting controlled research protocols in such a challenging environment. For instance, the utilisation of wearable technology, such as heart rate monitoring devices, on yawing and rolling vessels poses practical difficulties when sailing offshore for multiple days (12). Hence, as a substitute to objective exercise intensity, the researchers in this study used the RPE to quantify the psycho-physiological responses to training (12). Moreover, sRPE is a practical method for measuring WL completed through various training modalities such as cross-training and resistance training (35). WL_{mono} and WL_{str} indexes can be calculated from sRPE data methods. WL_{mono} is a measure of day-to-day training variability and has been found to be related to overtraining when monotonous training is combined with high WL_{wk} (11). WL_{str} has been found to be an advantageous tool as recovery only becomes fundamental to training when high WL_{wk} are being undertaken (32).

The observed variations in WL during the 27-week pre-competition period were substantial, indicating a noticeable difference between sailing and non-sailing weeks. Indeed, a difference of 703 % in WL_{wk} was found between weeks of training during sailing camp (19792.6 ± 9428 AU; W_{17-18} & W_{23-26}) and on land training weeks (2813.2 ± 817.3 AU; W_{1-16}, W_{19-22} & W_{27}) (Figure 2A). Additionally, a reduction of 50.4 % was observed in WL_{wk} during the taper week (3116.3 ± 712.7 AU; W_{27}) compared to preceding WL (6731.5 ± 8497.3 AU; W_{1-26}) (Figure 2A). The significant difference (*p*<0.001) in WL between sailing weeks and non-sailing weeks highlights the complex nature of planning within the training regimen. Indeed, variations in WL may be due to the numerous extraneous weather and environmental conditions as confirmed in previous research (1). Moreover, the considerable CV in WL_{wk} distribution (CV=1.18) emphasises the challenge of managing WL in the sailing setting. Although similar values of WL_{wk}, during non-sailing weeks, have been reported in other sports (8), the exceptionally high WL quantities observed during sailing weeks remain unparalleled.

To date, research focusing on the sailing environment has predominantly focused on aspects such as energy expenditure, sleep deprivation, nutritional challenge and epidemiology, yet WL management is conspicuous by its absence. Recently, high WL have been associated with risks of overtraining, injury, and decreased performance (8). Consequently, because of the high WL_{wk} observed in this study, the necessity for strict WL monitoring practices in offshore sailing environments seems crucial for optimising human performance. Beyond the observed WL patterns during TOR preparation, the study also delved into analysing the impacts of various WL parameters on neuromuscular function, wellbeing, and stress hormone levels.

Throughout the season, fluctuations were noted in the monitored indices. While past research has concentrated on establishing predictive associations between neuromuscular adaptations and sports performance (3), investigations into environment-based sports, such as sailing, are yet to be fully investigated. The results found in this study could, therefore, provide valuable insights for WL management in such environments.

Current literature has observed the impact of offshore sailing on lower body strength and power exertion (31). Notably, maintaining postural control through constant muscular tension, due to hull movement, appears to increase the mechanical loading of hip extensors and hip flexors and, thus, impair CMJ performance during and post-competition (31). CMJ assessments are commonly used to assess neuromuscular fatigue in professional athletes (7). In this study, the negative correlations found between WL parameters (WL_{wk} and WL_{str}) and the CMJ seems to be in agreement with research analysing the effects of WL on muscle power (21). Additionally, high chronic WL has been associated with inflammatory response, catabolic state and muscle damage which results in neuromuscular disturbances (23). Hence, this could partially explain the adverse effects of WL_{wk} on CMJ as TB_6 was a high sailing volume block and provoked a 15 % decrease, from $Test_5$, in CMJ performance. These results coincide with findings highlighting neuromuscular disruption due to the constant proprioceptive muscle tension encountered by sailors during the yawing, rolling and pitching motions of the hull (38). Furthermore, a 55 % decrease in WL_{wk} during TB_7 resulted in supercompensation from TB_6, positively impacting CMJ performance (+14 %). This highlights the sensitivity of CMJ performance to both fatigue and overcompensation (3).

Contrary to expectations, our findings revealed a notable increase in strength expression (BP_{1RM}) alongside the rise in WL_{wk}. Interestingly, although on land training WL (i.e., resistance training and metabolic conditioning) decreased exponentially after TB_3 (Figure 3), BP_{1RM} evolved positively (Table 1). The vessel in this study was equipped with upper body pedestals used to hoist and trim sails by driving the winches attached to the sail lines. The physical action of grinding, engaging these upper body pedestals, has received considerable amount of interest in sailing literature (29). The demands placed on the upper body during grinding have been well-documented, linking bench press performance to both sailing performance (29) and manoeuvre efficiency (26). Furthermore, the work-to-rest ratio, while using the pedestals, appears to facilitate adequate recovery between bouts of intense activity (26) and thus potentially mitigating the risks of overtraining. This may explain the positive upper body neuromuscular adaptations in response to a high sailing WL.

A novel aspect of the hereby study was the monitoring of professional sailors' perceptual wellbeing throughout an entire pre-competition period. To the best of the authors' knowledge, past research in offshore sailing has shown interest in establishing dose-response relationships between environmental and wellbeing factors such as anxiety and perception of fatigue (15). Similarly, when comparing to longer assessments (i.e., QEFA Likert scale), the HI has been found to be (i) a promising tool for monitoring training induced fatigue in team sports (28) and (ii) has shown associations with WL in professional athletes (25). In our study, the $Test_{1-7}$ HI was found to be positively correlated with WL_{wk}, WL_{str} and WL_{mono}. These findings are of important value when aiming to bridge the gap between WL and fatigue markers. The HI can therefore be considered as a cost-effective and practical means of monitoring both physiological and psychological stress in professional sailing environments.

From a physiological perspective, fluctuations in C may significantly impact both neuromuscular and cognitive performance. For instance, cortisol could influence the sympathetic nervous system's activity, alter muscle contractile properties and/or behaviour and serves as a primary indicator of physiological stress (19). There is a substantial body of literature addressing cortisol concentration increase in response to WL and competition. In the current study, the interactions between WL (WL_{wk} and WL_{str}) and C were predominantly clear. Indeed, the hormonal response to training appears to be impacted by short (7-days) preceding WL. This observation is similar to findings in other team sports (34) where C increased in response to WL. In our study, the C concentrations at $Test_6$ were the highest observed during the pre-competition period and were significantly different from baseline levels. These results suggest that high sailing WL may have an impact on stress hormone balance. This is in-line with reported studies that have analysed biomarkers in sailing activities (14). Furthermore, the increase in C could reflect the athletes' natural response to the previous training phase (28).

While our findings provide important and novel information for performance practitioners in offshore sailing, several limitations warrant consideration. First, we acknowledge that the data was collected on a small sample of sailors (i.e., one team). The use of larger sample sizes (e.g., more teams) would allow further and more precise correlational analysis. Second, caution is warranted when interpreting the reported hormonal concentrations as the Soma Bioscience device may potentially underestimate C levels compared to gold-standard ELISA (24). Third, due to sailing's dependency on climatic variables, the training structure may represent a different organisation when compared to other sports. Future research, based on sailing, could therefore explore the effects of sailing WL on adaptation markers via daily measurements. Moreover, exploring external load (e.g., GPS tracking, manoeuvre count) may prove to be useful for establishing valid methods able to quantify sailing WL. Furthermore, the absence of research concerning WL management in sports characterised by prolonged training sessions raises caution regarding data analysis. Indeed, the validity and reliability of the sRPE method in such activity has yet to be explored. Hence, exploring these aspects becomes necessary for a more comprehensive understanding of WL dynamics in extended-duration sports.

This is the first longitudinal study to provide information on WL parameters within a professional mixed-sex crew offshore sailing team during the preparation period of TOR. This investigation observed (i) significant differences between BSL levels and periodical evaluations and (ii) significant correlations between WL parameters and neuromuscular performance, wellbeing and stress hormone levels. Furthermore, objective markers such as BP_{1RM}, CMJ and C may be used as indicators of preparedness for an offshore regatta. HI may provide valuable information concerning physiological and psychological stress with less time-consuming/costly procedures. The results presented in this study confirm the importance of managing WL in professional offshore sailing in the quest to optimising training related adaptations and recovery.

FUTURE RECOMMENDATIONS

This study offers foundational insights into the intricate relationship between WL and key parameters such as neuromuscular performance, wellbeing, and stress hormone levels within the unique context of offshore sailing. Given the substantial and variable nature of WL within this setting, daily monitoring during pre-competition phases becomes imperative. This continuous assessment not only enables a comprehensive understanding of the fluctuations in WL but also equips performance practitioners with invaluable guidance. Through this data analysis, practitioners can adeptly (i) adapt training plans to suit dynamic environmental conditions, (ii) furnish skippers with crucial insights into potential injury or overtraining risks, and (iii) strategically devise and ensure adequate recovery interventions to enhance performance. In essence, this study underscores the pivotal role of systematic WL monitoring in the domain of offshore sailing. Such proactive and data-driven approaches not only fortify injury prevention strategies but also serve as a cornerstone for fostering peak performance, ultimately contributing to the overall success and well-being of professional sailing crews.

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DISCLOSURE OF INTEREST

The authors report there are no competing interests to declare.

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ETHICAL APPROVAL

Ethics for this study were approved in line with the University of Pau and Pays de l'Adour's Institutional Review Board

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