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Original Article

Effects of wind intensity on cognitive functions of young sailors in training

IVÁN CAÑELLAS GONZÁLEZ[1], BERTA BENITO COLIO[2], LUIS MANUEL MARTÍNEZ-ARANDA[3], FRANCISCO TOMÁS GONZÁLEZ-FERNÁNDEZ[4]
[1,2] Department of Physical Activity and Sports Sciences, Comillas Pontifical University. CESAG, Palma, SPAIN
[1,2] SER Research Group. Comillas Pontifical University. CESAG, Palma, SPAIN.
[3] Department of Physical Activity and Sports Sciences, Universidad Católica de Murcia, SPAIN
[4]Department of Physical Activity and Sports Sciences, Universidad de Granada, Facultad de Ciencias de la Educación y del Deporte de Melilla, SPAIN

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Abstract:
The general fatigue level of athletes seems to influence their level of vigilance. Atmospheric elements seem to highly contribute to this deterioration, especifically the wind. The aim of this study is to analyze the alertness of a group of sailors during three training sessions prior to a competition. For this purpose, eleven young sailors in training at national level from Real Club Náutico de Palma, Palma de Mallorca, Balearic Islands, Spain (age: 13.09 ± 1.58) were analyzed during three sessions: control group, with wind, without wind. The results showed that no prior differences in reaction time (RT) were observed between the control group and the wind condition group. However, an ANOVA with the participants' average RT between no-wind condition and wind condition, and task time revealed significant results ($F(1,9) = 10.40$, $p < .01$, partial $\eta 2 = .53$). The subjects show greater mental fatigue on windy days, which implies better results on less windy days. This is explained by their vigilance due to the inverted U, even when there is no correlation between different wind conditions and expertise, and neither between different physical conditions and age. However, as the literature shows, athletes that are mentally fatigued make more mistakes because of external and internal elements. In conclusion, on days with a higher wind intensity, sailors experience greater general fatigue, which leads to a poorer performance and a lower cognitive function. On days with little wind, sailors are less fatigued and therefore more attentive. Furthermore, all of the above is influenced by the level of the athlete.
Key words: sailing, **psychomotor performance, children, vigilance.**

Introduction

Sailing is one of the most popular water sports in the world. This sport is characterized by the control of the dynamics of a boat through the wind (Lóriga, Hourruitiner & Utrera, 2018). In fact, sailing is fundamentally manifested through the prism of two different perspectives: i) recreational (whose objective is the experimentation and enjoyment of this sport discipline), and ii) competition (a moment where the knowledge and skills that some athletes have in relation to others are shown).

As we have already mentioned, sailing is a complex sport comprising numerous parameters related to performance, the ability to understand and anticipate weather conditions, optimal equipment, boats and sails, as well as technical and tactical understanding (Bojsen-Møller et al., 2015; Spurway et al., 2007). Therefore, during competitions it is necessary to monitor and perceive all these parameters, and to assess the general fatigue level of the sailors, which is increased due to the effort of the athlete. To the best of our knowledge, once a certain level of fatigue is reached, the efficiency of the task that is being performed at that moment decreases simultaneously. This is explained by the fact that high-level mechanisms such as sustained attention or vigilance levels drop. It is well known that vigilance -which is crucial for sustaining attention over long periods of time- is a high-order function. This function determines whether goals are maintained and enables the development of adequate attention levels to respond quickly and accurately to relevant stimuli. Furthermore, researchers suggest that an adequate level of vigilance has a significant influence on the functioning of higher-level attentional mechanisms, such as cognitive control. The concept of vigilance is related to the attentional cognitive function to determine the capacity to respond appropriately to relevant stimuli (Sarter, 2001). In the laboratory, it is typically investigated doing tasks which consist of the monotonous presentation of stimuli for a relatively long period of time. This, required the participants to detect infrequent situations (Parasuraman, 1987) or to respond to unpredictable target onsets (Basner, 2011). The psychomotor vigilance task (PVT) has been widely used as a reliable research tool to analyze this cognitive function in a laboratory setting, and has been supported by neuroimaging studies. The PVT has become perhaps the most extensive method to measure behavioral alertness, mainly owing to the advantages over other cognitive tests (Lim, 2008; Dorrian, 2004).

Corresponding Author: BERTA BENITO COLIO, E-mail: bbenitocolio@gmail.com

The standard 10-min PVT quantifies sustained or vigilant attention by recording response times (RT), visual or auditory stimuli that take place at random inter-stimulus intervals (ISI) (Dorrian, 2004; Dinges, 1991; Warm, 2008).

In relation to the above and in the search for automation of technical movements, it is necessary to mention that managing stressful situations -such as the ones faced by an athlete during a competition- as successfully as possible without affecting the results, making athletes able to think quickly and provide accurate responses, and avoiding or minimizing athletes' fatigue are key aspects to increasing the performance of a sailor (Sleight, 2008; Johnson, 2006). However, among the uncontrollable elements that could directly influence the fatigue of an athlete are the weather conditions (Pinsach et al., 2002). In that sense, with regard to the sport that concerns us in this work, the wind would have a direct influence. This is usually measured in knots. Each knot is equivalent to 1.8 kilometers per hour. From there, the different forces can be seen: force 0 (less than one knot), force 1 (one to three knots), force 2 (four to six knots), force 3 (seven to ten knots), force 4 (eleven to sixteen knots), force 5 (seventeen to twenty-one knots), force 6 (twenty-two to twenty-seven knots), force 7 (twenty-eight to thirty-three knots), force 8 (thirty-four to forty knots), force 9 (forty-one to forty-seven knots) and finally force 10 to 12 (over forty-eight knots) (Sleight, 2008).

It is believed that, through different wind intensities, athletes can perform to a greater or lesser degree depending on their level of concentration. Because of this, different hypotheses arise about the influence of the wind on the cognitive level, reflected in sustained attention or vigilance of young sailors in training. Likewise, despite the importance of sailing as a sporting discipline and its high recognition as such, there are few studies in this area due to the difficulty of being able to make valid and consistent records of data on the water. Thus, no studies have been found that collect measurements of physiological or cognitive responses during regattas. However, there is research that examines simulations of regattas conducted on the water or using laboratory sailing dynamometers (Bojsen-Møller et al., 2015). Therefore, this research attempts to elucidate the influence of wind on an athlete's cognitive functions according to their overall fatigue level at specific moments of the competition in an ecological manner. Thus, it is expected that sailors perform significantly better in terms of cognitive attention (PVT) in favorable contexts (i.e., no wind).

Material and Methods

Participants

The participants were a total of eleven young national level trainee sailors from Real Club Náutico de Palma, Palma de Mallorca, Balearic Islands, Spain (age: 13.09 ± 1.58; height: 157.64 ± 7.59; weight: 46.04 ± 5.28 and BMI: 18.72 ± 5.51). In addition, this group had a previous experience of 5.18 ± 1.31 years and partook in weekly training of approximately 9.64 ± 1.50 hours. The inclusion criteria for the participants in this study were the following: i) to be an active and federated sailor, ii) to not have suffered any injury during the last two months, iii) to have consent from their parents or guardians, iv) to participate in all the research sessions and v) to be an athlete competing in regional or national championships. All the sailors in the study were treated in accordance with the guidelines of the American Psychological Association (APA), which guarantees the anonymity of the participants' responses. The study was also favorably approved by the ethics committee of the Universidad Pontificia de Comillas, 25 April 2021.

Instruments

Three types of tools were used depending on the information to be recorded. The first tool was intended to collect cognitive data; a second tool was used to record the anthropometric characteristics of the athletes and, finally, the Borg scale to assess the intensity of the conditions.

Cognitive tasks. In order to collect data related to sustained attention or vigilance, the psychomotor vigilance task (PVT) is used. Eleven mobile phones were used (one per athlete) and a computer application specifically designed to measure the attentional capacity of the sailors [Apple by California (IOS, version 13.3.1). The center of the screen of the device was located between 60 and 80 cm away from the participants' heads and at eye level. The app was used to control stimulus presentation and data collection. Participants' responses were collected by tapping the screen of the device (see Figure 1). The PVT consisted of the presentation of numbers in the center of the screen, which started to fill in at the speed of a real stopwatch and could be presented on the screen after a random time interval ranging from 2000 to 10000 ms. Prior to the start of the PVT in both sessions, verbal instructions were provided to the participants, emphasizing that they had to fix their eyes on the center of the screen, trying not to move their eyes and to respond as quickly as possible while avoiding anticipation. The task comprised a single block lasting 10 minutes.

Anthropometric characteristics. A SECA® wall-mounted stadiometer (model 206, Hamburg, Germany) was used for height-controlled measurements of the participants' physical fitness. Body composition variables (% fat) were analyzed using a TANITA® (InnerScan. BC-731, Arlington Heights, Illinois).

Subjective Scale of Exertion (Borg). The Borg scale (Borg, 1982) was used to record subjective perception of exertion (PSE), which has a range of perceived exertion from one (very light) to twenty (very hard). Although the participants had experience with this scale, as in the previous case, a test was carried out to ensure that the intensity of the session met the recommendations of ACSM (2010). The subjective perception of exertion data

was monitored immediately after each training session.
To conclude this section, the sports equipment used by each participant during the intervention will be shown different types of sports equipment were used to perform the training sessions correctly. The athletes used the following materials: (1) Optimist (Winner or Naaix models), (2) Sails (North or One Sails), (3) Pole (Optimax), (4) Beak (Optimax), (5) Boom (Optimax), (6) Different lines for sail trimming (Dinema and Tecnora Gotifredi), (7) Rudder and centreboard (DSK), (8) personalized sports clothing for each athlete. In addition, the coaches used: (1) Zodiac (Narwhal), (2) Anchorages to anchor the buoys, (3) Buoys to mark the route taken during training.

Procedure

The following sessions were carried out for this study:
First session (Control condition): during this session, several steps of great interest were carried out. Firstly, the eleven athletes and their parents were called together to inform them about the study and its objective. Once the explanation had finished, the athletes went to a different room and the parents stayed behind to sign the data protection and transfer of data form together with the information and consent form (see Appendix 1). When this was completed, the athletes returned for the data collection phase. Age, body weight, height, body fat, experience and training volume during the week were recorded (see Table 2). Subsequently, in the same room, with no noise or distractions for the athletes, a familiarization session of the application was carried out. Once completed, the first test was started to record the control test.
*Second session (wind condition) data with wind: Durin*g this second session the training session planned by the coaches was carried out. The training consisted of a course: upwind, downwind, downwind, stern, and upwind, a course that was planned for the regional, national, and international competitions in which they were going to participate. Once they had finished, the athletes were taken ashore, and the test was carried out there to find out how attentive the athletes were on a day of high intensity. The athletes were taken ashore, and the test was carried out there to find out the attention of the athletes on a day with an intensity of between eleven and fifteen knots (Force 4). Finally, the questionnaire was used to record the Borg scale (Borg, 1982).
Third session (Without Wind condition): During this session, the same procedure was carried out. Firstly, the training session was carried out (on this occasion, the wind intensity was between two and six knots, i.e. the intensity was Force 2. Then, once on land, the PVT was carried out and finally the Borg scale (Borg, 1982) was recorded.

Data analysis

The present research has an intra-subject design with the conditions: (i) wind condition (low intensity and medium intensity) and time condition, i.e. time spent on the task. The task was divided into 1-minute blocks to investigate the time course of reaction time in the PVT (total of 10 minutes). To perform the data analysis, an analysis of variance (ANOVA) was performed to analyze the reaction time data. In addition, a t-test was used to analyze the differences in the intensities of the two sessions. It should be mentioned that the data was analyzed with appropriate statistical methods to calculate percentages, central and dispersion parameters (through arithmetic means and standard deviations). A Pearson's correlation coefficient r was used to examine the relationship between age and expertise RTs in the different conditions. To interpret the magnitude of these correlations, we adopted the following criteria: $r \leq 0.1$, trivial; $0.1 < r \leq 0.3$, small; $0.3 < r \leq 0.5$, moderate; $0.5 < r \leq 0.7$, large; $0.7 < r \leq 0.9$, very large; and $r > 0.9$, almost perfect. Effect size is indicated as a function of Cohen's d values for t-tests and eta squared for Fs. The Greenhouse-Geisser correction was applied when sphericity was violated (Jennings & Wood, 1976). In such cases, corrected probability values were reported. Data were analyzed in Statistica software (Version 13.0; Statsoft, Inc., Tulsa, OK, USA). For all analyses, significance was accepted at $p<0.5$.

The results of each PVT were recorded on each mobile device and sent for further processing. Finally, a total of 11 subjects were recorded for 3 different conditions (control, wind condition and no wind condition). From the final analysis, one athlete was excluded due to erroneous performance of the task due to misunderstanding the task. A filtering was performed in which trials with RTs shorter than 100 milliseconds were excluded (Basner & Dinges, 2011). Anticipation errors were discarded from the analysis.
Different repeated measures analyses of variance (ANOVA) with the mean Reaction Times of participants with the condition [control condition (335.92 ± 9.88); no wind condition (329.75 ± 12.90); wind condition (344.90 ± 19.30)] and time on task (10 minutes) were performed to try to elucidate the aim of the study

Results

As can be seen in Figure 1, the results show that the participants' mean reaction time (RT) (control condition Vs no wind condition) and task time revealed no effect of condition or time, $F<1$, thus demonstrating that the two conditions did not have different priors. Secondly, an ANOVA with participants' mean RT (no wind condition Vs wind condition) and task time revealed a significant main effect of effort condition, $F(1,9) = 10.40$, $p<.01$, partial $\eta2=.53$.

Participants responded faster in the no wind condition (329.75 ± 12.00) than in the wind condition (335.92 ± 9.88). No time or interaction effect is shown. Finally, a new ANOVA (control condition Vs wind condition) and task time revealed no main effect or F<1. As shown in Figure 1, participants generally responded faster in the no-wind condition (329.75 ± 12.90) than in the wind condition (344.90 ± 19.30).

Complementarily, a t-test was performed with the data of subjective perception of effort after performing both conditions of effort. Thus, the results showed higher values in the wind condition (5.82 ± 0.98) than in the no wind condition (3.36 ± 0.50), t (10) = -9.75, p<.001, d=3.16.

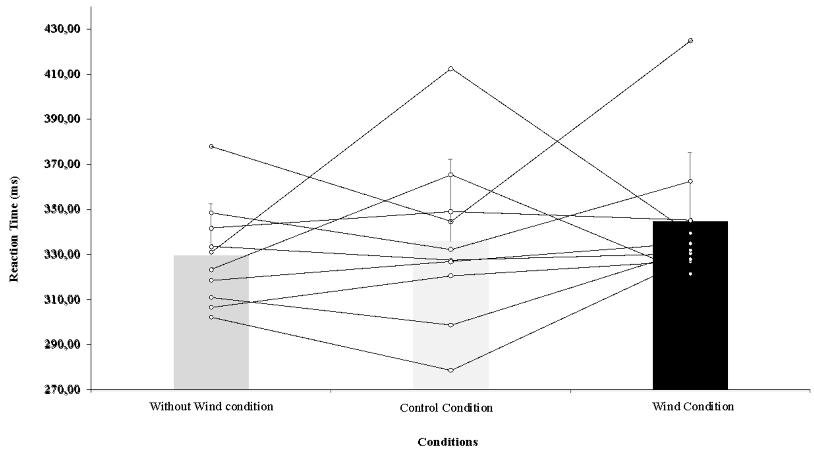

Figure 1. Average reaction times (± SD) and individual results as a function of condition.

Correlation analyses were performed between different conditions and expertise in years. Crucially, there was no correlation between different conditions and expertise, and neither was there between different conditions and age (see Table 1). In addition, we present figures 2 and 3 to allow for observation of the dataset trend.

	Expertise	Age
Without Wind Condition	r= -0.49 *p*= 0.14	r= -0.06 *p*= 0.67
Control Condition	r= -0.34 *p*= 0.34	r=-0.11 *p*= 0.75
Wind Condition	r= -0.23 *p*= 0.52	r=-0.24 *p*= 0.85

Table 2. Correlation between without wind condition, control condition and wind condition expertise and age.

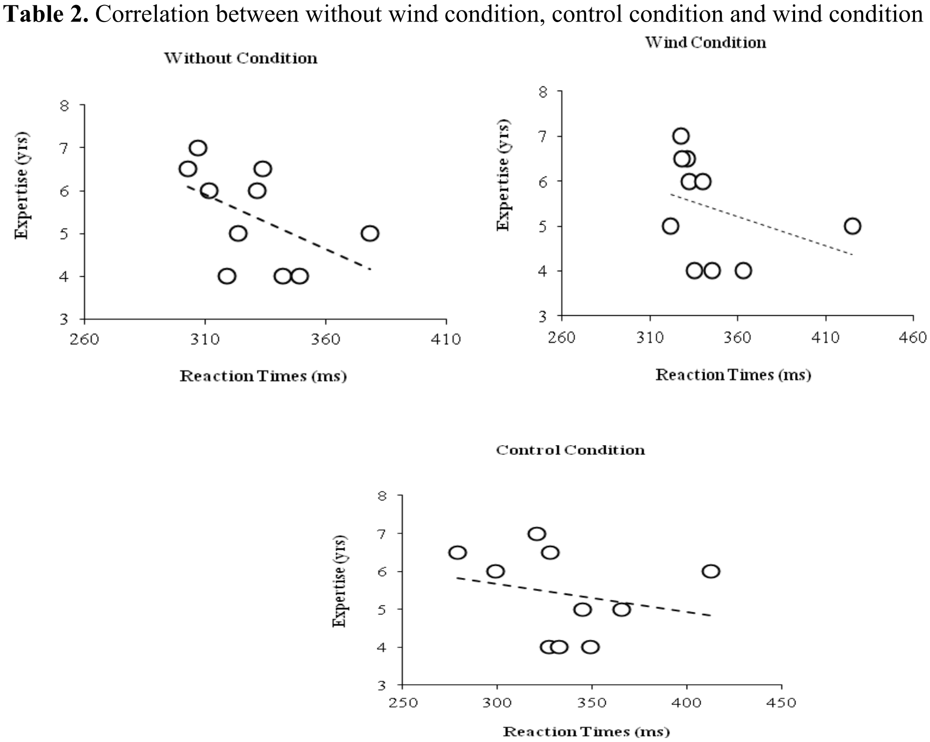

Figure 2. Representation of correlations between expertise (years) and reaction times in different conditions.

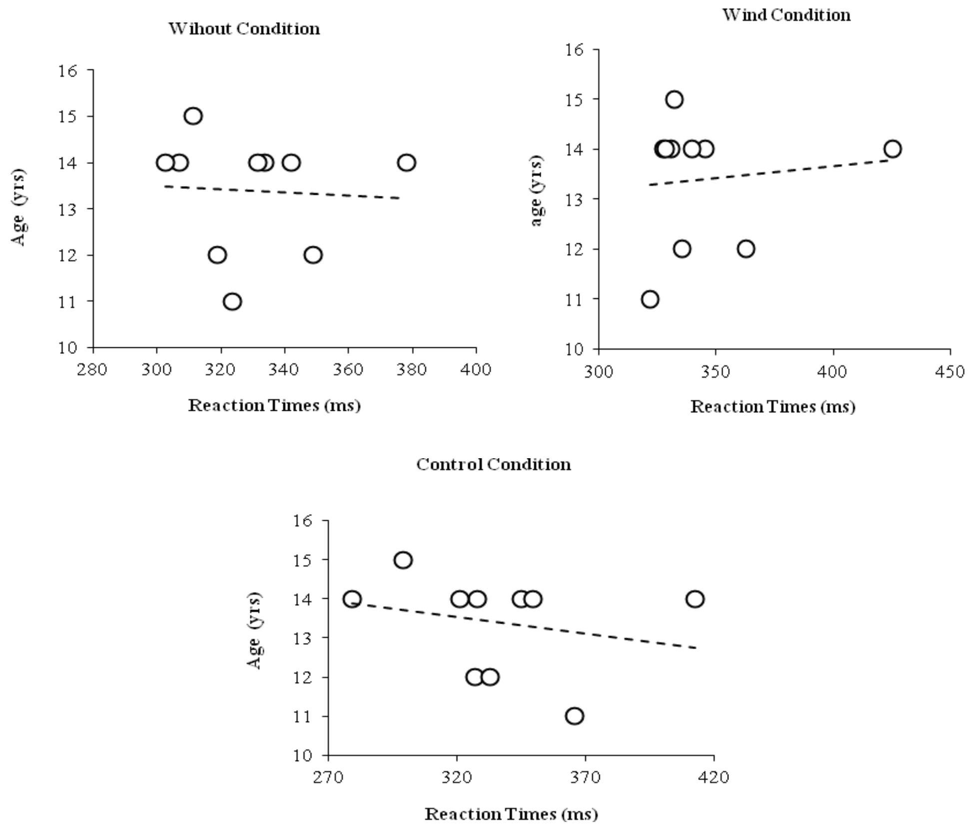

Figure 3. Representation of correlations between Age (years) and reaction times in different conditions.

Discussion

Despite the importance of sailing as a sport and the large number of boys and girls competing in the Optimist category, there are few studies on the cognitive response of sailors during sailing. Because of this, it is interesting to be able to analyze in detail the cognitive functions of the sailors and their reaction time as a function of their level of fatigue.

Firstly, the low body weight is consistent with the anthropometric profile of the sailors who sail in Optimist, since, as López (2016) explains, the small size of this type of boat demands a specific profile of a sailor, who will be of around 40-45 kg. In this way, the anthropometric profile of the sailors responds to specific characteristics, especially in terms of weight. In the event that a subject had an early maturity with a notable increase in body weight, he or she would switch to a larger boat. Furthermore, the results found are consistent, as are the anthropometric characteristics of the analyzed subjects, which are similar to those found in other studies (Callewaert et al., 2014; López et al., 2016).

Another element to be considered is the relationship between an athlete's level of fatigue and their level of performance and cognitive attention. It is believed that what determines the variations in PVT performance is the intensity of the exercise through the inverted U, where the peak of performance is found in the light-moderate effort, while if you are above or below that intensity, vigilance obtains a higher or lower performance depending on the intensity that is established in the session. In other words, the results show that the subjects show greater mental fatigue on windy days, therefore, the attention tests result, are higher than on days when it is less windy. Thus, by observing these results, we can determine that they are within the vigilance due to the inverse U. Even though, results also show that there is any correlation between different conditions and expertise and neither between different conditions and age.

The results presented here are consistent with the literature that has been analyzed on the influence of mental fatigue on performance Smith et al. (2016) found that mentally fatigued football players made more errors in passing and shots on goal. While Alarcón et al. (2017) say that the more fatigued amateur basketball players have, the more their technical gesture performance is negatively affected. In these studies, it was determined that mentally fatigued participants increased the number of errors in cognitive and athlete-specific tasks (Alarcón et al., 2017; Boksem, et al., 2005; Lal & Craig; 2001). Although there are expert players who have automated the specific movements or technical elements of the sport they play, in those that require a lot of precision and speed the athlete has a very high percentage of cognitive failure (Alarcón et al., 2017). It should also be noted that this automation does not prevent the deterioration in performance under conditions of physical fatigue (Freitas, et al., 2016; Mokou, et al., 2016). These results, in the sport of sailing, can be explained by the fact that sailors have to think about several elements when sailing in windy conditions. That is, the position they have to maintain due to the boat exerting force horizontally creates muscle fatigue. In addition, having to keep an eye on the fleet, the wind, the sea and all the conditions explained above at all times creates mental fatigue. As Pageaux et al. (2013) point out, in addition to whole body endurance, mental fatigue also affected muscular endurance. Moreover, it can be pointed out that these conditions are unstable (they change from moment to moment), athletes must be more attentive to achieve the highest possible speed at all times.

With respect to the conditions without wind, these results are obtained thanks to the fact that the wave conditions are non-existent, a factor that is already eliminated from the fatigue.

Wind conditions are less, but this is another factor that increases fatigue along with the fleet. In contrast, muscle fatigue is much lower (see Table 3) when the Borg Scale is recorded. It can be observed that they score higher on days with higher wind intensity. One of the possible alternative hypotheses may occur due to the stress suffered by the athlete because this provides a feedback of the result that can generate a negative emotional state and not get all the attention that is sought from the subjects. As no differences were found between the three days of the tests, it is ruled out that these could have been the cause of the differences in performance. It is also true that, as we have no previous literature, due to the fact that this is the first study that works on cognition in sailing, we cannot rely on any parameter to determine our hypothesis, which is why this study is not entirely reliable, as we would need more literature to draw a clear conclusion. Even so, it is possible to indicate that, if more studies are carried out with larger samples, it would be possible to determine whether our study can be reliable. Also, we have drawn ideas for future studies that can help us to determine mental fatigue, i.e. whether what really affects is that the level of attention is higher without wind or whether mental fatigue is worse with wind.

Practical implications and future research

The results of the present study emphasize a potential finding that highlights the influence of wind on athlete's cognitive functions according to their overall fatigue level at specific moments of the competition in an ecological manner. In other words, it is expected that sailors will perform significantly better in terms of cognitive attention (PVT) in favorable contexts (no wind). In fact, the results guarantee an important research topic in this population and contribute to demonstrating the evidence of young sailors. All gathered data, testing assumptions, and the search for physiological and behavioral patterns in these populations also contributes to the research. Future studies may analyze if the understanding of the concepts of physical and cognitive fatigue for a part of young sailors may induce more favorable effects to endure the training intensity. In addition, young sailors should be responsible for the perception of intensity as physical fatigue and for its relationship with cognitive fatigue as demands of training. In addition, future research will focus on creating different instruments that connect both measures.

A practical application of this work shows the evidence on physical and cognitive fatigue of intensity and try to determining the most adequate and practicable physical condition strategies by technical and physical staff in order of organize the more important physical contents in face of weekly preparation and also specially in week of competition (two or three journeys to competition with different wind conditions). In sum, this review provides key information about the intensity control in sailor, as the factors that have been monitored can be taken into account to select the best athlete needed considering his individual fitness and cognitive level in order to improve the overall team performance.

Conclusion

The outcome of the present study suggests that on days with a higher wind intensity, sailors experience greater general fatigue, which leads to a poorer performance and a lower cognitive attention (PVT) and function. Thus, it can be concluded that the wind has a direct influence on the overall fatigue of the sailor and, consequently, on his or her cognition and performance. It can also be agreed that on days with little wind, sailors are less fatigued and therefore more attentive.

On the contrary, on windy days, the cognitive and attentional functions of the sailors are lower. The importance of these findings is partly due to the fact that there is no study that analyzes what is proposed in this research, being the first contribution for the scientific community. Therefore, there is still a long way to go examining sailors' performances both in competition and in training. Finally, it can be observed that there is a direct relationship between the level of the athlete and the results of the tests carried out in this study.

Therefore, those athletes with better scores in both regional and national regattas recorded lower reaction times in the tests of the control session, in the test with wind and in the test without wind. In conclusion, all the elements discussed must be understood in order to assess their impact on vigilance in young sailors.

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