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Performance enhancing strategies in sailing sports: beyond training and nutrition

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review paper
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ANDREA PAGLIARO[1,2], ANNA ALIOTO[1,2], CARLO ROSSI[1,2], SARA BALDASSANO[3], PATRIZIA PROIA[1]

[1] Sport and Exercise Sciences Research Unit, Department of Psychology, Educational Science and Human Movement, University of Palermo, Palermo, Italy
[2] Centro Medico di Fisioterapia "Villa Sarina", Alcamo, Italy
[3] Department of Biological Chemical and Pharmaceutical Sciences and Technologies (STEBICEF), University of Palermo, Palermo, Italy

ABSTRACT

Purpose. Sailing is a water sport comprising several disciplines distinguished by the type of boat and number of crew. The sailor must constantly accommodate the movement of the hull according to the weather conditions. The study aims to provide targeted guidance regarding training and nutrition for sailor athletes.

Methods. Complete and effective training requires a synergistic combination of sport-specific elements and strategies designed to improve overall strength. Extensive discussion has been made of the types of workouts aimed at improving performance and preventing injury.

Results. Our research findings revealed that even though sailors' training considers the development of strength, endurance, speed, balance, and coordination, which are necessary to counteract the continuous adaptations of posture to weather conditions, these athletes are exposed to the risk of injuries that predominantly affect the knee and lower back. Sailing is an aerobic/anaerobic sport in which there are no explicit suggestions regarding the nutritional aspect and supplementation and what their contribution could be in improving performance.

Conclusions. We hypothesise that targeted training paths for sailing athletes and personalisation of nutritional suggestions by timing the intake of macro- and micronutrients as well as taking specific supplements, can reduce the risk of injury and better impact recovery and performance in this discipline.

Key words: sailing boats, sport, training, nutrition, supplementation, ergogenic aids, performance enhancement

Introduction

Sailing is a sport determined most of the time by weather conditions. Sailors must constantly steer into the wind by trimming their sails to keep the hull balanced, improving performance and thus the outcome [1]. Optimal performance depends both on the ability to interpret and exploit the wind in one's favour and on the combination of anthropometric, physical, technical, and tactical factors. Regattas may comprise a single race or a series of races known as 'manches' and may be spread over several days depending on the weather conditions. At the end of the race, the total scores are added up to determine the final ranking, identifying the winner of the race. Typically, boats line up along the starting line and wait for the sound signal indicating the start of the competition. The boats sail through a predetermined course that includes turns and bowlines (stretches where they sail into the wind) to reach the finish line. The route may vary depending on the weather conditions. In these competitions, tactics and wind management are key weapons for successful performance. These competitions are governed by specific rules laid down by the International Sailing Federation (World Sailing) and may follow additional regulations specific to the boat's class or venue [2]. The study by Bojsen-Møller et al. shows that there are various classes of sailors who develop muscular strength and

Correspondence address: Patrizia Proia, Sport and Exercise Sciences Research Unit, Department of Psychology, Educational Science and Human Movement, University of Palermo, Via Pascoli 6, 90144 Palermo, Italy, e-mail: patrizia.proia@unipa.it; https://orcid.org/0000-0002-0326-5560

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endurance skills depending on the type of boat they belong to [3].

In particular:

– Hikers: They sit on the deck of the boat and lean over the side, with their feet secured under bilge straps. The classes are Laser, Laser Radial, Finn, and 470 Helmsman.

– Side hikers: these are sailors who adopt a different 'hiking' position from the traditional position, in which they move sideways relative to the centre of the boat rather than keeping their weight above the boat longitudinally. This 'side hiking' technique may involve more extended body positions laterally relative to the boat.

– Trapezing sailors: They stand on the edge or side wings of the boat, supported by a cable extending from the shrouds. They are part of the 49er, 49erFX, Nacra 17, and 470 crew classes.

– Board sailors: a discipline in which people use a board with a sail mounted on a mast to sail by exploiting the wind. These athletes are also known as windsurfers or board sailors.

In particular, we will deal with sailors known as hikers who use a dinghy with only one member on board or with a crew of two. In this class of boat, success depends on the navigator's ability to counteract the forces that threaten the boat's balance, causing a sideways tilt called 'excursion'. To stabilise the boat during these forces, the navigator performs a specific technical movement called an 'edge excursion'. Through this movement, their body acts as a counterweight: by placing their feet in the straps in the centre of the boat, they tilt outwards to balance the forces acting on the boat. The primary objective of this manoeuvre is to ensure stability, allowing the sailor to make the most of the force of the wind to increase the boat's speed throughout the course [4]. During a competition, around two-thirds of the total time is spent sailing into the wind, a phase that requires intense and constant physical effort. This involves the use of both metabolisms, aerobic and anaerobic, which involves the use of all energy substrates. This could be helped by taking specific supplements that function to counteract fatigue more effectively (e.g., by opposing exertion-induced acidification) and restoring the energy substrate of anaerobic metabolism (such as phosphocreatine) more quickly [1].

Muscular engagement in sailing hiking positions

During regattas, optimal performance is essentially made up of the athlete's ability to effectively counteract two external forces: lateral thrust, which acts perpendicular to the main axis of the boat, causing it to tilt sideways, and a second force used when sailing against the wind to advance upwind. This countering of external forces requires not only technical skills and navigational prowess but also considerable physical strength developed by the athlete, enabling them to maintain the stability of the boat and optimise the propulsion [5]. The length of time these athletes spend in a 'hiking' position during a race can vary greatly depending on the race conditions. In general, athletes spend most of the race in the 'hiking' position, as this posture is essential to control the boat, maintain balance, and optimise speed, especially in stronger wind conditions. However, the specific duration can vary from short periods where athletes change position to adapt to wind conditions, to long stretches where they remain constantly in a 'hiking' position to make the most of the ideal wind and boat speed conditions. In the hiking position, the sailor strives to keep the boat balanced against the force of the wind, positioning the body to counteract the force that tilts the boat. This position requires a series of muscle contractions to maintain the balance and stability of the boat. Although static muscular contractions predominate, there are small constant adaptations involving movements and adjustments to react to changes in wind forces and to maintain balance. This dynamic aspect, albeit minimal, makes the position 'almost isometric'. Therefore, although it is primarily isometric, the dynamic nature of the small adaptations makes the hiking position a kind of hybrid between isometrics and a dynamic muscle contraction [6–8].

Hiking positions are crucial in sailing. Two of the main ones were identified in a recent study of young sailors. One is the short stance, in which the torso remains rigid while the knees and hips are flexed. The other is the long posture, in which the torso, hips, and knees are relatively extended. Both of these postures can be performed statically or dynamically, showing variations in the conformation of the body during hiking [9]. In another study focusing on the physical characteristics of dinghy sailors, three different hiking positions were identified. These include 'sitting hiking', with a closed hip angle between 90 and 120 degrees, 'upright hiking' with an angle between 120 and 150 degrees, and finally 'extended hiking' with a hip angle between 150 and 180 degrees. These different positions illustrate significant variations in body posture when hiking on these boats [1].

One can understand how altering these positions during a regatta generates massive recruitment of certain muscle groups. The major muscles involved are:

– Quadriceps muscle: located in the anterior portion of the thigh; it is the main extensor and stabiliser of the knee in the long and short hiking positions [9];

– Ischiocrural muscles: these are three muscles located in the posterior portion of the thigh, involved in knee flexion, hip extension, rotation, and stabilisation of the pelvis. These are highly stressed in the long position.

– Spinal muscles: they are divided into two major categories, the superficial muscles and the deep muscles. Their main function is to support, stabilise, and enable movement of the spine in different directions, thus providing structural and functional support to the trunk and the entire musculoskeletal system in the hiking position [7];

– Abdominal muscles: involved in stabilising the upper body, they are fundamental for maintaining an efficient body position throughout the technical gesture [10].

Muscular strain, injuries, and training strategies in sailing hiking

The hiking manoeuvre is a muscularly complex technical gesture, which needs the correct training to be maintained for as long as possible. The main point of discomfort in prolonged hiking is the strain on the quadriceps, which are responsible for supporting the weight of the body against the force of gravity. To understand this load, it is essential to note that the thighs assume almost fixed positions when the body is fully extended. They are effectively 'locked' between the upward thrust of the side of the deck just below the mid-thigh and the downward forces on the ends of the femur: the former is generated by the weight of the trunk and upper body acting on the hips, while the latter is given by the tension of the straps on the feet, positioned close to the centre line of the boat. Although these straps directly affect the feet, their force is transmitted to the femur due to the extension tension of the quadriceps muscles on the knee [6]. The strong stress on the target muscles is caused by the unequivocal partial ischemia typical of prolonged isometric positions. Thus, with the maintenance of these prolonged positions, physiological consequences may occur, such as a reduction in blood flow with consequent overload of the cardiac system and lactate production [11–15]. The constant movement of adjusting the body through the hiking technique in response to wind and sea conditions leads to a continuous overload of the athlete's muscles. It is no coincidence that the most frequent sites of injury reported by athletes are the knee at 19%, the lower leg at 13%, the shoulder at 12%, and the lower back at 11%. 44% of knee injuries occurred during sailing activities and 26% during physical training [16]. In a study conducted to assess the proper function of the knee, the relationship between the strength of the quadriceps and the strength of the ischiocrural was examined. The investigation revealed a significant imbalance in the strength between the quadriceps and ischiocrural muscles, which could be the cause of increased knee injuries. During hiking, sailors must constantly adapt their position to react to changes in the wind and waves, resulting in constant stress and extension of the quadriceps muscles. This prolonged activity can increase the pressure on the anterior cruciate ligament of the knee and lead to rapid muscle fatigue, forcing sailors to predominantly use the vastus lateralis muscle, which can result in knee pain [17]. In several studies, it has been shown that activities such as hiking can significantly increase the risk of developing low back pain (LBP). Annual incidences of LBP between 13% and 94% and lifetime prevalence between 29% and 69% have been reported, and this is not surprising given that among sailors in the Olympic classes, LBP is the most common musculoskeletal injury, with an incidence of 53% [18]. In another study, dynamic hiking and off-water activities showed significant overloading in the lumbar region among sailors [14]. This was also found in a study by Hunt et al., in which a medial collateral ligament (MCL) injury was reported after training caused by excessive force on the knee joint. The authors of the latter study worked on an athlete-specific rehabilitation protocol to shorten recovery time [19].

In the literature, there seems to be a scarcity of methodologies concerning improving performance out of the water. This deficit is due to the difficulty of faithfully reproducing the hiking position. Injuries that primarily affect the knee joint and back do not only affect those specific muscle groups. They often occur with a broader impact on other connected areas of the body. This connection highlights the importance of developing global strength to ensure greater resilience and prevent future injuries. To achieve greater strength and stability in the entire body, it is crucial to integrate comprehensive strength exercises that also involve the upper body. This approach provides adequate stimulus to the core and upper body, helping to improve stability and reduce the risk of back problems. Physical training plays a key role in reducing the risk of LBP. Higher levels of fitness, which include not only increased trunk muscle strength but also adequate endurance, have been associated with a lower risk of LBP.

Investing in overall body strength can offer better protection against injury and promote long-term health [18, 19.

Energy management and optimised training in sailing

In sailing, accurate energy management is critical to maximising performance. Targeted supplementation plays a crucial role in providing support during intense efforts. Athletes can benefit from supplements that counteract muscle fatigue and promote rapid recovery of necessary energy, thus optimising their ability for sustained, high-performance performances [1].

At the same time, specific training plays a decisive role in optimising the body's energy efficiency. Targeted training programs not only enhance the muscular endurance involved in hiking positions but also help optimise the use of energy substrates during navigation. For example, resistance exercises improve the efficiency of aerobic metabolism, allowing athletes to better manage prolonged efforts against the wind [20].

This integrated approach, combining targeted nutritional supplementation and a suitable training program, not only optimises performance but also helps reduce the risk of fatigue and muscle injuries resulting from prolonged activity in specific positions [21].

The role of nutrition on performance is already demonstrated in different sports disciplines [22]. Due to the relationship between anthropometric characteristics and sports performance, nutrition also plays an important role in ensuring adequate energy levels during training, competition, and recovery [23, 24]. Considering the current scientific void surrounding the relationship between sailing, injuries and the nutritional impact on the practice of the sport itself, our review aims to provide targeted guidance to promote optimal performance and prevent sailing injuries through training and nutrition.

Material and methods

Training and performance in sailing

The literature currently lacks scientific evidence regarding our topic, which is why we based our work on the few studies presented in the literature.

There are a few studies in the literature that have explored specific training in sailing as well as targeted interventions to improve the performance of sailors in various sailing disciplines, and the most representative are indicated in Table 1.

These studies have focused on a wide range of populations, from Olympic elites to youth sailors, examining rehabilitation interventions, and functional conditioning, and evaluating the effectiveness of specific exercises and training protocols.

Hunt et al. [19] studied the rehabilitation and strengthening process in elite sailors, highlighting the return to competition with significant scores of 80/80 on the functional assessment scale. Similarly, El Beih et al. [10] showed a 12.20% increase in core strength thanks to a specific functional training program.

In other studies, such as the one conducted by Vangelakoudi et al. [11], levels of anaerobic capacity and isometric endurance were analysed, highlighting greater power and endurance in elite sailors compared to amateur sailors. Studies such as those by Burnett et al. [9] examined muscle activation and adaptation to the specific demands of hiking, emphasising the importance of injury prevention and rehabilitation.

Finally, research such as that of Friesenbichler et al. [7] explored the analysis of concentric, eccentric, and isometric muscle strength, highlighting greater strength in specific muscle groups in sailors compared to non-sailors, highlighting the impact of aerobic exercise and counter-resistance.

These studies reflect the broad spectrum of interventions and approaches used to improve sailors' performance, highlighting the importance of targeted and specific training protocols for each sailing discipline (Table 1).

Therefore, sailing typically involves both aerobic and anaerobic training, often alternating during a single sailing or racing session. This sport requires a complex mix of efforts that involve both energy systems, which therefore requires a considerable nutritional plan and/or contribution.

Training strategies and injury prevention

A methodological approach for complete and effective training requires a synergetic combination of sport-specific elements and strategies aimed at improving general strength. Such a structured approach may be optimal for ensuring steady and lasting progress, requiring detailed planning divided into three main macro-cycles.

The first of these cycles, commonly referred to as the off-season, is the ideal time to lay the foundations of general strength by focusing on the fundamental movements of strength training. During this phase, the focus is on building a solid base of strength to serve as a foundation for subsequent development. This is

Table 1. Overview of studies concerning methodological training approach

Study/ research	Study population	Type of intervention	Exercises	Results
Sun and Pan [17]	45 well-trained sailors (age 21 ± 3.7 years)	Lower limb power and explosive strength training	– Warm-up: 10–15 min (pedalling at 60–80 rpm – Isokinetic dynamometry – Counter-movement jump – Cool down: dynamic lower limb stretching	The results showed the hikers had higher quadriceps isometric PT
El Beih et al. [10]	Laser radial sailors (n = 10, age 18.5 ± 3 years)	Functional core conditioning	Isometric (static) exercises on stable surfaces (hiking bench). Isokinetic (dynamic) concentric exercises on stable surfaces were added to the routine. Isokinetic (dynamic) concentric exercises on unstable surfaces were introduced, using tools such as Swiss ball, BOSU ball, balance on boards and laser boat simulator	A core-specific training program led to significant improvements in sailors' strength, stability and endurance. After eight weeks, there was an improvement of 12.20% in the main test
Vangelakoudi et al. [11]	National and Club Sailors (age 22 ± 2 years)	Fatigue resistance was compared between professional and amateur sailors.	Laser sailing simulation test; resistance test on a specific. Laser sailing simulator. Isometric strength test. An isometric strength test was performed on the dominant leg on an isokinetic dynamometer. Wingate Anaerobic Test: a 30-second test to evaluate anaerobic power on a cycle ergometer	Sailors demonstrated greater isometric and Laser endurance, with less fatigue during the anaerobic test. The exercises aimed to evaluate isometric resistance and anaerobic power related to sailing performance
Burnett et al. [9]	Junior sailors (n = 29; age 14.1 ± 0.7 years)	Strength and conditioning training	In this study, there were 2 test sessions separated by at least 48 hours: session 1: lower-limb strength exercises; session 2: warm-up, strength and conditioning and stretching	The results showed that muscle activation levels obtained through strength and conditioning exercises at the 6RM intensity can be used to provide an overload stimulus for the sail excursion
Friesenbichler et al. [7]	15 elite professional sailors and 15 non-sailing controls (average age 27 ± 2 years)	Muscle strength and endurance were compared between elite sailors and non-sailors.	Evaluation of the isometric, concentric and eccentric strength of the trunk and knee muscles. Trunk muscle endurance testing. Measurement of muscle thickness of the trunk and knee muscles using ultrasound	Elite athletes showed greater strength and muscular endurance in the trunk and knee muscles, particularly important for maintaining specific positions during navigation

a period in which athletes can focus on the progressive acquisition of strength, concentrating on key exercises involving the fundamental muscle groups. This is followed by the pre-season phase, in which a reduced intensity level is maintained in fundamental work, while specific exercises related to the sport practiced are introduced. During this phase, the aim is to integrate movements and motor gestures typical of the sporting activity, while maintaining a basic approach aimed at improving general strength. This period serves as a transition between the development of basic strength and the practical application of specific exercises.

Finally, we arrive at the in-season phase, characterised by the emphasis on sport-specific preparation. During this period, the work on basic strength is further reduced, focusing mainly on optimising sport-

specific technical gestures. The aim here is to maintain a sufficient level of strength to support sports performance without overloading the musculoskeletal system [25–27].

To ensure optimal adaptation of the entire body and promote high-level performance while minimising the risk of injury, it is advisable to integrate a wide variety of exercises into the training program. This variety should cover a range of general and specific exercises, including both heavy- and light-load exercises [28, 29]. Within the practice of sailing, elite athletes face specific demands in terms of muscular strength and endurance. Muscle groups such as the quadriceps, ischiocrural, paravertebral, and abdominal muscles are essential to ensure body stability during 'hiking' manoeuvres, in which it is necessary to produce the correct movement while maintaining adequate stability. The most common injuries among sailors often involve the lower back (45%), knees, and shoulders (22%). These injuries may be the result of functional overload, inadequate physical preparation, or incorrect use of hiking techniques, which generate high mechanical stress due to incorrect postures. Considering the complexity of hiking manoeuvres and the high risk of injury, especially on the quadriceps and lumbar area, it is advisable to integrate exercises aimed at developing muscular power, to reproduce the specific movements of the sports activity, involving the muscles in their specific working angles. Strengthening the muscles involved and reproducing the characteristic movements of the activity in question can be an effective strategy, especially if preceded by a general development of muscular strength. For example, exercises such as squats, deadlifts, and good mornings, performed correctly, can favour the massive development of back muscles, abdominal muscles, spinal erectors, gluteal muscles, and ischiocrural muscles in anatomical positions and angles relevant to the demands of hiking. Variation of exercises, such as the back squat performed at different degrees of knee flexion, can provide complete muscle strengthening, especially when greater hip extension is considered, generating significant levels of strength throughout the body when performed correctly [30–32]. An exercise that is often underestimated, but which could greatly benefit athletes without taxing the knee joint, is the front squat. This, because of the position one assumes and the possibility of generating a high-force engagement, generates a simultaneous improvement in the abdominal muscles, the spinal erectors, and the quadriceps.

Furthermore, adapted to the athlete's needs, e.g. performed in controlled degrees of knee flexion, it could help athletes with meniscal injuries to strengthen the anterior thigh muscles [33]. The introduction of exercises such as the hip thrust or Romanian deadlift, performed with different support modes, monopodalic or bipodalic, can provide varying adaptation stimuli to both the nervous system and the muscle groups involved. The variety of exercises, presented with varying degrees of complexity, helps athletes adapt to situations of inequality or disadvantage, which is especially relevant in an unpredictable sport such as sailing [34]. The inclusion of general strength exercises could further strengthen the muscles, helping to effectively support the load on the back and quadriceps, thus reducing the risk of injury. A body that is accustomed to working under sub-maximal loads and in unbalanced situations may offer better support during the most demanding phases of competitions, promoting better performance over time.

Ethical approval

The conducted research is not related to either human or animal use.

Nutrition and supplements for hikers

In recent years, sports performance has been assessed using anthropometry as a reference, especially in sports such as recreational sailing [35, 36]. Among the parameters analysed are body mass, height, thigh length, and body mass index (BMI) [37]. This could influence performance, as it facilitates a specific technical gesture called a hiking bench [4]. This was induced by the change in the sailing format as a result of the development of specific physical and physiological requirements of the sailor, such as muscular endurance and strength [3]. The technical gesture is mainly aimed at counteracting the forces generated by the effect of the wind [38]. Therefore, the greater the body mass, lower limb length and height, the greater the lever arm available to the sailor and thus the force the sailor can develop. However, the anthropometric characteristics of athletes over the years have changed, so continuous updating would be necessary. Some studies have shown a direct relationship between sports performance and anthropometric characteristics [39, 40]. What influences the change in anthropometric characteristics is nutrition, which affects athletes' performance, endurance, and overall health [41]. Nutrition is much more than energy supply because it includes proper timing in the intake of macronutrients and micronutrients, as well as the maintenance of hydration. It also has

a fundamental impact on recovery from the exertions of training and competition.

However, while racing, access to nutrients may be limited due to both a lack of space and a lack of time. The importance of a balanced diet for athletes is now well known; it assumes the intake of carbohydrates, proteins, and fats and does not neglect hydration. Another key aspect is meal timing; in fact, eating at regular intervals throughout the day ensures a constant supply of energy. Malnutrition or low nutrition can have a detrimental impact on athletic performance such as weakening and muscle loss, induced by a lack of protein intake that can hurt performance in strength-dependent sports such as sailing or increase the risk of injury. In fact, poor nutrition could compromise bone health, making athletes more susceptible to stress fractures and injuries [42]. In addition, poor nutrition could slow recovery from exercise-induced muscle damage. This could lead to a reduction in training frequency and intensity [43]. Thus, a planned pre-race meal program can certainly provide benefits to the athlete by taking into consideration training and competition schedules. It is now well known how adequate carbohydrate intake can assist in improving endurance, while the co-intake of protein and carbohydrates after exercise can result in improved recovery [44].

During physical activity, glycogen stores play a key role in athletes' performance since the released carbohydrates play a key role in maintaining blood sugar levels. Therefore, an insufficient intake of carbohydrates will have an impact on decreasing muscle and liver glycogen stores and consequently reducing athletes' endurance and performance [45]. Protein also plays a very important role not only in muscle growth and maintenance but also in the repair of damaged muscle fibres and for the synthesis of enzymes involved especially in energy metabolisms, to maintain fitness and performance [46].

Moreover, the physical effort required during sailing is so intense that it induces an alteration in pH and an increase in ketone concentration [47]. The metabolism of athletes thus finds itself facing increased energy demand and stress induced by exposure to endurance exercise and fasting. This results in the initiation of metabolic strategies aimed at implementing fuel economy [48]. An increase in the utilisation of lipid metabolism is also shown by the change in the level of circulating ketones [49–51].

Some nutritional strategies are implemented to improve energy intake. For example, carbohydrates taken before activity can induce benefits in increasing muscle glycogen energy stores; this can have a positive effect on exercise endurance and also on delaying the onset of fatigue. Many ergogenic supplements such as creatine and β-alanine are recognised for their benefits in improving recovery after exercise and injury prevention but also for potential neurological benefits that may be relevant to sports. Regarding creatine, the ergogenic effects include not only increasing muscle phosphocreatine stores but also replenishing its levels during recovery from exercise [52]. It has been shown that creatine and carbohydrate supplementation can increase creatine phosphate accumulation and retention [53]. It has been reported that taking creatine with carbohydrates or both carbohydrates and protein more consistently promotes greater creatine retention. As for

Table 2. Overview of studies concerning nutrition requirements and supplement consumption in sailing

Reference	Subjects	Duration of survey	Results (nutritional requirements/ supplements)
Macro and micronutrients			
Gogojewicz et al. [43]	10 windsurfers	3 days during national windsurfing championship	↓ Energy intake ↓ Hydration ↓ Vitamin D and calcium ↑ Cholesterol
Verma et al. [56]	37 sailors	1 month over one month of training	↔ Energy intake (macro and micronutrients)
Bernardi et al. [57]	15 sailors	3 days of activity	Diet unbalanced towards fats
Fearnley et al. [50]	1 sailor	45 days	Underconsumption of carbohydrates
Lewis et al. [58]	11 sailors	3 days	Dehydration
Sports supplement			
Caraballo et al. [59]	42 sailors	3 days	Dextrose, β-alanine
Portier et al. [60]	12 sailors	2 days	Branched chain amino acids (BCAA)

β-alanine, when combined with L-histidine, it forms the dipeptide carnosine. It has been shown that during short-duration, high-intensity physical training, carnosine can act as a buffer on the increase of H^+ ions. This is one of the main reasons why it is used as an ergogenic supplement, especially in vegetarian athletes who have lower muscle carnosine levels than omnivorous athletes [54, 55]. Also to be considered is the use of dietary supplements such as energy bars (fruit bars, granola bars, protein bars, fibrous bars, etc.), sports drinks, sports juices or energy gels, pre- and post-workout as an energy supply, and support for restoring used energy reserves. An overview of the main studies in the literature about the main nutritional deficiencies and supplements taken by sailors is shown in Table 2. As can be seen, the studies in the literature on this topic are limited and therefore need further investigation.

Results

Our study highlights that traditional training protocols for sailors significantly emphasize the development of essential physical attributes such as strength,

Table 3. Guidelines are inherent to a generic training week and the appropriate nutritional and supplementation needs, including pre-, during, and post-race days.

Day	Training type	Nutrition recommendation	Supplementation
Monday	Strength training	Pre-workout: meal with lean protein, complex carbohydrates, vegetables. Post-workout: meal with protein for muscle recovery, carbohydrates for restoring glycogen reserves	Beta-alanine (2–3 g split into three doses) before the workout. Creatine (5 g) after workout
Tuesday	Cardiovascular training	Pre-workout: complex carbohydrates. Post-workout: meal with protein for recovery	Caffeine (100–200 mg) 30 min before workout
Wednesday	Active rest	Focus on antioxidant-rich foods to reduce inflammation (vegetables and bluefish)	No specific supplementation
Thursday	Strength and power training	Pre-workout: meal with slow-release carbohydrates and protein. Post-workout: meal with protein and carbohydrates	Beta-alanine (2–3 g split into three doses) before workout. Creatine (5 g) after workout
Friday	Cardiovascular training and sailing technique	Carbohydrates to sustain energy during training	Sports drink during training for hydration and carbohydrate/electrolyte supplementation
Pre-race	Active or light rest	Balanced and light meals to avoid gastrointestinal discomfort during the race. Adequate hydration, avoiding radical changes in diet.	Beta-alanine: could be taken to improve muscle support and delay fatigue during activity
Race		Before the race: breakfast with slow-release carbohydrates, protein and adequate hydration	Possible caffeine supplementation to improve concentration and alertness. Sports drink containing carbohydrates and electrolytes for hydration and energy supply
		During the race. Hydration and nutrition: regular consumption of water or electrolyte drinks to maintain hydration. Light, easily digestible snacks (such as dried fruit, energy bars) to maintain energy without weighing down the stomach.	Sports drink: supplement with a sports drink containing carbohydrates and electrolytes to support energy and hydration during the race
		After the race. Recovery: balanced meal with carbohydrates, protein and healthy fats for muscle recovery and replenishment of energy reserves. Hydration: continue to hydrate adequately after the race	Beta-alanine to improve muscle support and delay fatigue during activity

endurance, speed, balance, and coordination. These attributes are pivotal for effective navigation and agile response to the continuous challenges presented by variable weather conditions. However, a critical insight emerges: despite such structured training, athletes remain vulnerable to specific contextual injuries, particularly affecting the knee and lower back. This injury pattern suggests a direct correlation with the unique biomechanical demands of sailing, which imposes a series of physical stresses that can easily exceed the body's tolerance thresholds if not precisely managed. Moreover, our research underscores a critical gap in nutrition and supplementation approaches. Remarkably, despite sailing being an activity requiring a blend of aerobic and anaerobic efforts, there is a significant absence of clear, tailored nutritional guidelines for sailors. This lack of guidance could prevent athletes from fully optimizing their performance potential, limiting their ability to support the energy demands and recovery requirements imposed by competition and training.

Conclusions

Based on the findings, we propose that a more targeted and personalized approach to training and nutrition could not only minimize the risk of injuries among sailors but also significantly enhance their performance. Customizing training pathways, with a renewed focus on injury prevention through specific exercises targeting vulnerable areas (such as the knee and lower back), could provide a solid foundation for improving athletes' physical resilience. Concurrently, integrating a nutritional and supplementation program that accounts for the specific energy needs and recovery requirements of sailors could play a crucial role in optimizing their performance. Timing the intake of macro- and micronutrients, coupled with the strategic use of selected supplements, offers a promising avenue to better support athletes in their preparation and recovery. Ultimately, our analysis emphasizes the importance of a holistic and individualized approach that extends beyond the traditional focus on training and nutrition, highlighting the need for an integrated strategy that addresses the unique challenges posed by high-level sailing.

Practical application

Based on the current literature and the above discussion, it is possible to suggest guidelines inherent to a generic training week and the respective nutritional and supplementation needs, including pre-, during, and post-race days (Table 3). Of course, the guidelines specifically address the nutritional and supplementation needs inherent in pre- and post-work.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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