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DETERMINING FACTORS IN THE PERFORMANCE OF HIKING IN DINGHY SAILING: A LITERATURE REVIEW

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ABSTRACT

The aims of this study were to identify and analyse the research studies related to the sailing technique "hiking", as well as analysing the influential factors in this technique. The data was obtained from an analysis carried out on nine databases, limiting the investigation to the period between 1975 and 2013. The articles analysed in this review collected physiological, biomechanical, training variables, literature reviews and other studies that serve to show the technique in depth. Hiking is considered the most decisive technique in the performance of a boat dinghy with middle and high winds, which is aerobic and dynamic in nature, due to the constant movement that the sailor must perform while hiking to counterbalance the ship's movements. The quadriceps muscle is the most important for maintaining the position of hiking, being the muscle that reaches the higher percentage of maximum voluntary contraction (% MVC) and suffers more stress due to the high restriction of oxygen and perfusion associated with their high level of isometric work; while the knee is the joint that does more work, because of the higher moments of force applied during the action of hiking. As for the types of training, no specific training on this technique has achieved results applicable to practice.
Key Words: sail, hiking, dinghy

RESUMEN

Los objetivos de este estudio han sido identificar y analizar las investigaciones relacionadas con la técnica de navegación a vela denominada "sacar cuerpo", así como describir los factores influyentes en la misma. Los datos que se presentan fueron obtenidos a través de la búsqueda realizada en nueve bases de datos. Se delimitó la búsqueda a los artículos que hubieran sido publicados entre los años 1975 y 2013. Los artículos analizados en ésta revisión recogen variables fisiológicas, biomecánicas, de entrenamiento, revisiones bibliográficas y otros estudios, que han servido para describir en profundidad dicha técnica. La técnica de sacar cuerpo, de naturaleza aeróbica y dinámica debido a los constantes movimientos que el regatista debe realizar, es la más determinante en el rendimiento de vela ligera con vientos medios y fuertes. El músculo cuádriceps es el que mayor porcentaje de contracción máxima voluntaria alcanza y el que más estrés sufre, debido a las altas restricciones de oxígeno y perfusión que conlleva su alto grado de trabajo isométrico; igualmente, la rodilla es la articulación que mayores momentos de fuerza aplica durante la acción. No existe ningún entrenamiento específico haya demostrado resultados positivos sobre el rendimiento.
Palabras clave: vela, sacar cuerpo, vela ligera

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INTRODUCTION

In dinghy sailing, there are many types of vessels, (single or double, with or without trapeze, monohull or multihull, etc.) all of which demand certain small adjustments in their navigation, but a technical aspect that does not change from one boat to another is the technique of hiking, for the execution of which vessels possess an adaptation called a toe strap. This technique is a special manoeuvre whereby the sailor leans back, partly or fully, over the edge of the boat, in a horizontal position, keeping their feet attached to the toe strap. (De Vito, Di Filippo, Felici & Marchetti, 1993; Sekulic, Medved, Rausavljevi & Medved, 2006).

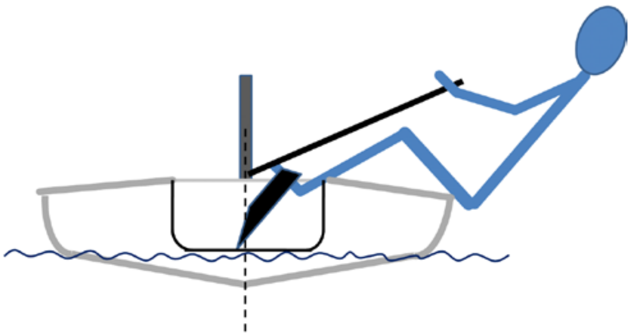

FIGURE 1: Hiking technique.

The hiking manoueuvre is required because the action of the wind on the sails causes the boat to heel, which increases its resistance and decreases its speed, making the use of hiking fundamental in order to correct the position of the boat with the aim of facilitating planning and, therefore, improving its speed and performance. (De Vito et al., 1993; Sekulic et al., 2006)

In order to stabilize the boat, counteracting the action of the wind on the sails, the sailor keeps their feet hooked under the toe strap close to the centreline of the boat, and holds the upper part or the body over the edge of the boat to exert proper force and keep the boat upright (Putnam, 1979).

Hiking is the manoeuvre which exerts the greatest physical demand in dinghy sailing (Larsson et al., 1996; Sekulic et al., 2006), characterized by strong isometric contractions of the muscles involved: quadriceps, hamstrings, abdominal and paravertebral muscles (Larsson et al., 1996; Tan et al., 2006). This technique is used when the wind exceeds approximately 12 knots or more (Sekulic et al., 2006). A race takes place from 3-4 knots of intensity up to 25-30 knots, depending on the class of vessel, so hiking is required in the vast majority of races.

According to Felici, Rodio, Madaffari, Ercolani and Marchetti (1999), Blackburn (2006) and Sekulic et al. (2006) the hiking position is not held for more than 20 seconds continuously, but rather alternates between three different positions: sitting upright, hiking in a vertical position and hiking with the body inclined backwards (Figure 2). The sailor sits upright when sailing in the direction of the course (downwind) in any wind condition, crosswind (perpendicular to the wind) on the run (oblique to the wind) and upwind (at 45º in the opposite direction to the wind) in light winds (0 to 7 knots). The sailor hikes in an upright position on the close-hauled course in medium winds (8 to 12 knots) and in crosswinds and on a run in strong winds (from 13 knots). Finally, the sailor hikes leaning backwards on the close-hauled course with strong winds and in the changes from windward to leeward (tacking) (Felici et al., 1999; Blackburn, 2006; and Sekulic et al., 2006).

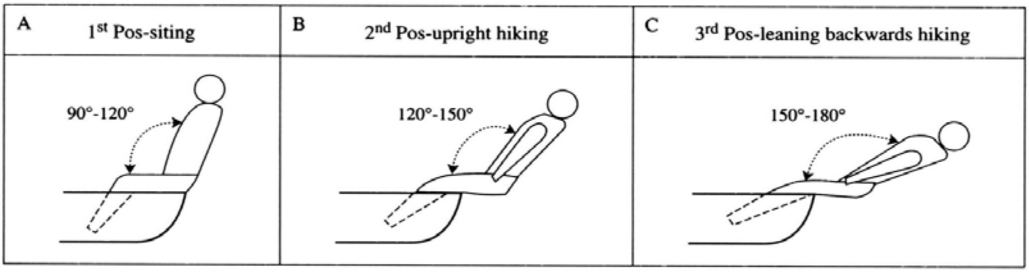

FIGURE 2: Typical hiking positions (adapted from Sekulic et al., 2006).

Along with tactical and strategic aspects it remains clear that in dinghy sailing performance is directly related to the ability of the sailor to counteract the external forces acting on the boat. An efficient hiking technique results in less friction between boat and water and therefore more speed (Sprada et al., 2007). From Castagna & Brisswalter (2007) we know that the total force applied by the wind on the sail in the horizontal plane can be divided into two components: one lateral force, perpendicular to the major axis of the boat which tends to cause it to heel; a second, which is used in the close-hauled course in order to advance. Therefore, the only means for keeping the boat horizontal is the sailor and his ability to hike for the necessary time, thereby improving the speed and performance of the boat. Blackburn and Hubinger (1995) reported that in dinghy sailors, the correlation between hiking resistance and performance in races was 0.82.

For these reasons, the objective of this study is to review all the previous studies carried out so far on this technique, in order to highlight and analyse the important aspects which can help to improve it in the future.

TARGETS

Therefore, the main objectives of this report were:

- To identify all the studies which describe the principal aspects of the hiking technique on dinghy sailing.
- To be able to identify the features of this technique to acquire a widespread and specific knowledge about it.

METHOD

Inclusion criteria

The inclusion criteria established for the search were: i) The research indexed between 1975 and 2013, ii) The research articles, which had studied the hiking technique on dinghy sailing, iii) The research articles, which had their complete content available.

Election of the articles to review

The referred database for the bibliographic research were: Proquest, ScienceDirect, SpringerLink, EBSCO, Ovid, ISI web of knowledge, PubMed, Dialnet and Google Academic. The keywords used were "sail*", "hiking" and "dinghy", which were also used in Spanish in some databases.

Documentation criteria

After the selection of the studies of the hiking technique, they have been catalogued in groups according to the most important variables of each study. The specific categories were: physiology, biomechanics, training, literature review and other studies.

RESEARCH RESULTS

Using the aforementioned search criteria, 64 articles related to the dingy sailing "hiking" technique were found. For this assignment 34 of the articles were studied. However, only those which were related solely to hiking were considered as opposed to those which described other aspects of dinghy sailing. The articles which were not considered either did not fulfill the inclusion criteria, were repetitions or simply did not contribute to the assignment's objectives.

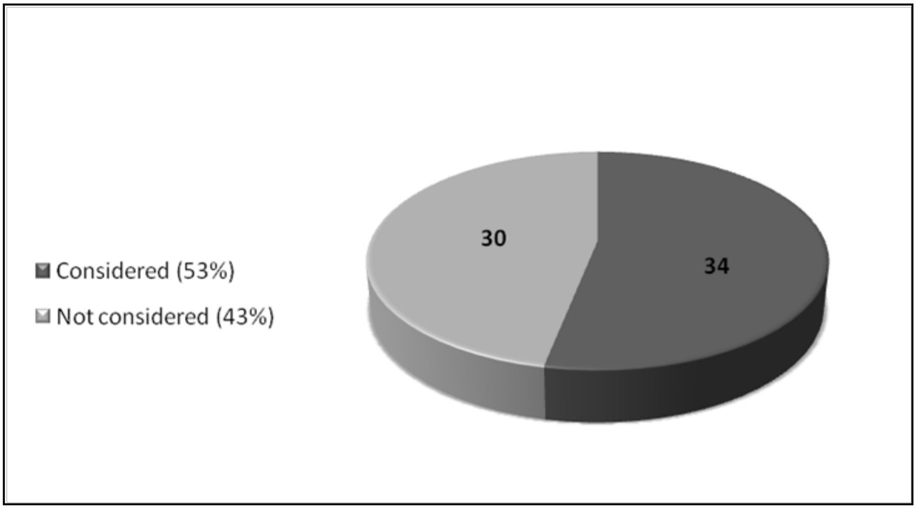

FIGURE 3: Percentage of articles considered or not considered.

Therefore, the articles which were considered were divided into the following categories: physiology, with 18 articles (53%), biomechanics, with 8 articles (23%), training, with 2 articles (6%), literature review, with 3 articles (9%) and other studies, 3 articles (9%).

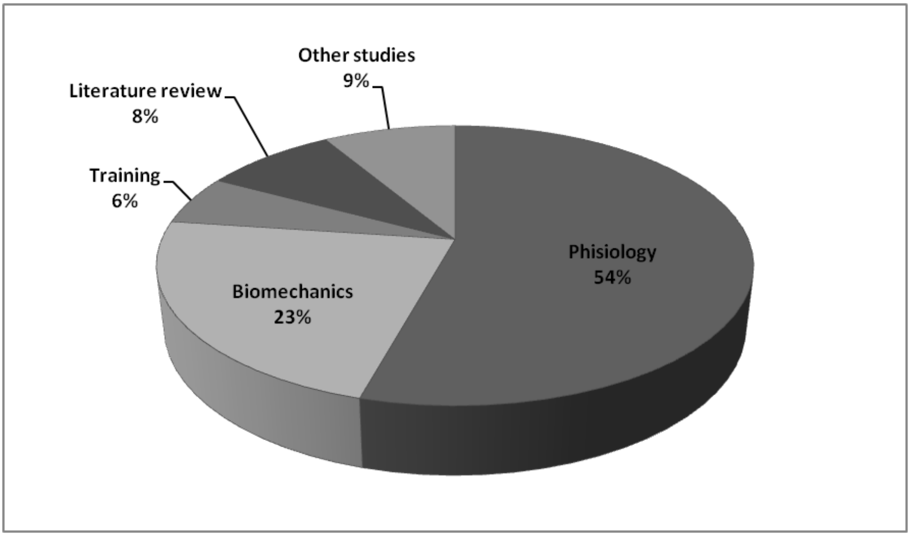

FIGURE 4: Percentage of articles considered based on their corresponding categories.

Next, the main discoveries that were found in the different categories will be described.

The physiological response during the hiking action

The physiological response study during the hiking position has been the area of study with the greatest scientific input in recent years with regards to dinghy sailing. Due to it being considered the most physiologically demanding manouevre in dinghy sailing (Larsson et al., 1996; Sekulic et al., 2006), the investigations carried out regarding the determining factors in the hiking technique have aimed to clarify the decisive variables in said technique in order to recognise and be able to improve them for a consequent increase in the yachtmen's performance during sailing.

One of the most interesting points (Manzanares, Segado & Menayo, 2012) is the findings regarding the intensity of the effort produced, for which variables such as VO2, blood pressure, heart rate and blood lactate were analysed, amongst others (Callewart, Boone, Celie, Clercq & Bourgouis, 2013; Castagna & Brisswalter, 2006; Cunningham & Hale, 2007; Felici et al.,1999; Vangelakoudi, Vogiatzis & Geladas, 2007; Vogiatzis, Tzineris, Athanasopoulos, Georgiadou & Geladas, 2007).

As seen in Table 1, it is difficult to compare the results which were obtained by each author with one another, be it due to the system used for data collection (VO2), or the great differences between data owing to different methods being employed in each study. Despite this, it was found that a yachtsman's VO2 when hiking would be around 58% of his VO2 max. (Cunningham & Hale, 2007). With regards to heart rate, it was found that there are no great differences between experts and novices (Brisswalter, 2006; Vangelakoudi et al., 2007). However, an average heart rate cannot be established due to the big difference in results. Blood lactate also showed great differences between studies. This was once again due to employing different methods, as was the case with blood pressure.

TABLE 1
Summary of the main physiological study results.

	VO2 max. (ml/kg/min)	Heart rate (BPM)	Blood lactate (mmol/L)	Blood pressure (mmHg)
Blacburn (1994)			2.32 ± 0.8	*Systolic:* 172 ± 18 *Diastolic:* 100 ± 14 *Arterial:* 123 ± 14
Callewart et al. (2013)	22.2 ± 3.8	136 ± 17		115 ± 20
Castagna &Brisswalter (2006)	***Experts*** 58.2 ± 4.7 ***Beginners*** 55.9 ± 6.9	***Experts*** 192 ± 4.3 ***Beginners*** 189 ± 4.2	***Experts*** 8.4 ± 1.5 ***Beginners*** 9.1 ± 2.8	
Cunningham &Hale (2007)	58.1(%)	160	4.47	
Felici et al. (1999)	0.95 ± 0.21 (min^{-1})			94
Vangelakoudi et al. (2007)		***Experts*** 149 ***Beginners*** 149		***Experts*** 129 ***Beginners*** 120
Vogiatzis et al. (2007)	12.2 ± 2	124 ± 10	3.2 ± 0.9	

Note: The average values obtained are shown. Where there are no average values. the maximums are shown.

All the studies shown in Table 1 measure a series of the yachtsmen's physiological variables whilst they are performing the hiking technique. However, it can be observed that the results obtained by different authors for the same variables are very different in some studies. This could be due to the method employed by each author being different from that of the rest. A solution to this problem when comparing results could be to establish a standard method when it comes to carrying out the hiking technique in laboratories so that when the effort intensity that is produced is measured, the results obtained can be compared.

Another factor which is considered by the authors to be important when clarifying if this technical movement is static or dynamic is blood flow. (Cunningham & Hale, 2007; Vogiatzis et al., 2011; Vogiatzis et al., 2007), in other words, if the yachtsman manages to hold a static position when hiking or if, on the other hand, he makes other movements whilst he holds this static position. According to these authors, the hiking position is dynamic and when in the position, blood lactate is low due to the muscles' partial reoxygenation in the short rest intervals. However, the vastrus lateralis suffers a reduction in oxygen availability due to blood flow being restricted in the quadriceps during the isometric periods of the hiking position. (Vogiatzis et al., 2011).

Electromyography (EMG) has also been very important in the study of this technique. Many authors (Callewart et al., 2013; Maïsetti, Boyas & Guével, 2006; Sekulic et al., 2006; Vangelakoudi et al., 2007; Vogiatzis, Spurway, Jennett, Wilson & Sinclair, 1996; Wee et al., 2010) have analysed the involvement of the muscles used in the hiking technique with the aim of understanding their degree of particpation in the technical movement.

TABLE 2
Electromyography based on different muscles. (% MVC).

	Quadriceps	Vastrus lateralis	Rectus abdominus	Tibialis anterior	Lumbar
Callewart et al., 2013		76.8 ± 29.6%			
Maïsetti et al., 2006		Right: 32% Left: 54%	Right: 32% Left: 37%		
Sekulic et al., 2006	Right: 99% Left: 109%		Right: 52% Left: 60%	Right: 2% Left: 2%	Right.: 2% Left: 5%
Vangelakoudi et al. 2007	Right: 70% Left: 70%				
Vogiatzis et al. 1996	39%				
Wee et al., 2010		10.3%	26.8%		13%

It can be observed that different protocols were employed for electromyographic measurements during the action. However, they all calculated it from % of the máximum voluntary contraction (%MVC) which was obtained during a previous test. From this data, one can gather that the quadriceps is the most involved in the hiking technique, in any of the three positions (figure 2), followed by the rectus abdominus, which increases its involvement proportionate to the intensity of the wind. In other words, it works the most when leaning back in the hiking position (Sekulic et al., 2006).

Finally, with regards to the energetic system involved in the hiking technique, the first investigations consider it to be a static and anaerobic technique (Manzanares et al., 2012). However, subsequent studies have shown that the yachtsman's continuous movement makes the technique an almost completely dynamic and aerobic movement with isometric moments (Cunningham & Hale, 2007; Marchetti, Figura & Ricci, 1980).

Biomechanic response during the hiking action

The hiking technique has been studied by various authors in the biomechanics field. The first was Putnam (1979) who designed a mathematical model to calculate the hip and the knee's articular moments in 3 different hiking positions. The first position analyses the yachtsman practically inside the vessel, the second when he is starting to hike (knee half-way up) and the third when his body is completely out (knee on the edge of the vessel); concluding that the last two positions demanded greater strength. Although, the optimum way to hike would be determined by the individual muscle features of each person. By way of explanation, each yachtsman will adopt a different position when it comes to angles and strength depending on the length and strength of their limbs.

Aagaard et al., (1998), measured the maximum isometric, concentric and eccentric forces of the extensors (quadriceps) and flexors (hamstrings), the knee and the trunk extensors with an isokinetic dynamometer. Their objective was to describe the isokinetic profile of the yachtsman, comparing it with a control group and then to connect it with perfomance when hiking. This said performance was measured in two ways: statically and dynamically. Statically speaking, the performance was measured using an exhaustion test whereby the yachtsman had to hold the hiking position with a static knee angle of 45º and hip angle of 75º. The test was repeated dynamically with the same static knee angle of 45º but with a dynamic hip angle of between 45º and 60º. A greater maximum eccentric effort in the yachtsmen's quadriceps was seen in comparison with the control group. Furthermore, correlations were found amongst the hiking performance and the maximum eccentric effort of the knee extensors ($rs = 0.67 - 0.74$, $p < 0.05$) and the maximum effort of the trunk extensors ($rs = 0.69 - 0.92$, $p < 0.05$). It is worth mentioning that it has been the only study where the measurements were taken in a real sailing environment, whereas all the others were evaluated in a laboratory.

Mackie (2003), established the following as key indicators of performance for the hiking technique: the angles adopted by the yachtsman in the lower part of the body's articulations (hip, knee and ankle), as well as weight (W), height (H), centre of gravity (CG) of the subject and the hiking distance (HD) (horizontal distance between the yachtsman's centre of gravity and that of the vessel), from which it is possible to calculate the "hiking moment (HM) = HD x W", which he considered to be the key element.

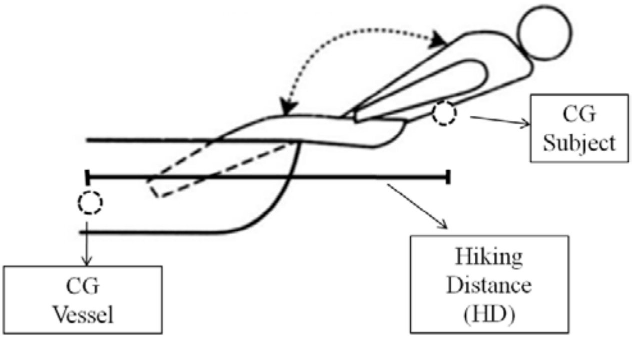

FIGURE 5: Explanation of the terms.

These variables can be evaluated by using kinematic systems (Beillot et al., 2001; Mackie, Sanders & Legg, 1999; Mackie, 2003; Sprada et al., 2007) when the coordinates are obtained using video cameras in order to calculate the CG, HD and therefore the HM.

Thus, Mackie et al. (1999) measured the lower body articulation angles adopted by the yachtsmen during sailing, along with the force exerted by the feet on the girth and the hand on the sheet. The force of the feet on the girth was 73-87% of the maximum voluntary contraction (MVC) predicted. On the other hand, the force on the sheet was 25-35% reaching peaks of 40-50%. Both forces were evaluated by simulating all of the sailing directions. They were greater up wind and lower downwind. The hip and ankle articulation angles increased when the wind got up sailing upwind, whilst the knee articulation angles decreased.

TABLE 3
Average angles and standard deviations (SD) of the ankle, knee and hip articulations for yachtsmen in four different dinghy sailing classes in two different wind conditions. (Adopted from Mackie et al., 1999).

Vessel	**Wind intensity (knots)**	**Average angle ± SD (degrees)**		
		Ankle	Knee	Hip
Europa	8-12	145 ± 11	155 ± 6	114 ± 11
	12-16	145 ± 4	138 ± 8	104 ± 8
Laser	8-12	155 ± 10	149 ± 3	113 ± 12
	12-16	155 ± 5	147 ± 5	125 ± 10
Finn	8-12	133 ± 7	120 ± 13	101 ± 13
	12-16	134 ± 9	125 ± 11	112 ± 8
470	8-12	131 ± 10	164 ± 5	102 ± 3
	12-16	146 ± 12	147 ± 6	121 ± 6

Sprada et al (2007) used this same kinematic system to analyse the movements of the spinal column, identifying the movements and adjustments of the yachtsman's trunk. In order to do this, they chose 3 angles in the sagittal plane (neck bending angle, thoracic kyphosis angle and lumbar lordosis angle), the angle of incline in the frontal plane and the rotation of the trunk in the transverse plane. The results they found were that the trunk's muscles were continuously making small adjustments during the hiking technique. This was because the video analysis showed a large number of variations in the spinal column in only 10 seconds, therefore contradicting De Vito et al. (1993) who considered that the trunk was a fixed, immobile section during the hiking technique.

As an alternative to the kinematic analysis systems which have been used to carry out the biomechanical studies on this technique in recent years, Schütz et al (2011) developed a dynamometric method for evaluating the hiking technique using force platforms which were placed underneath the simulator. They managed to pinpoint the CG of the vessel based on its position (horizontal or keeled over), instead of assuming that the CG was always in the median line of the boat as had been done in other studies (Mackie, 2003; Maïsetti, Guével, Ianchkine, Legros & Briswalter, 2002; Tan et al, 2006). As the HD depends on the boat's CG, a better positioning of it entails a more exact HD value and as a result, a more exact HM value produced by the yachtsman.

TABLE 4
Main biomechanical study results.

Authors	Study type	Aims	Sample number
Putnam, 1979	Kinetic	Present a mathematical model with which it is possible to calculate muscle moments and knee and hip articulation angles for the hiking technique.	N=10. Men, experience not specified.
Aagaard et al., 1998	Kinetic	Describe the isokinetic force profile and its relation to the elite yachtsmen's hiking performance.	N=29. 21 professional yachtsmen (15 M, 6 F) and a control group of 8 volunteers.
Mackie, Sanders &Legg, 1999	Kinetic	Evaluate the force applied by the feet on the girths and the hand on the sheet. Measure the angles adopted by the yachtsmen for the ankle, knee and hip articulations during the hiking technique.	N=11. International and national level yachtsmen from different olympic classes.
Sprada et al., 2007	Kinematic	Evaluate movements and positions of the yachtsman's spinal column during the hiking position.	N=1. International level yachtsman.
Schütz et al., 2011	Kinematic	Develop a dynamometric method in order to evaluate the hiking technique on laser-type vessels.	N=3. National level yachtsmen.

Training

Regarding the design and application of a training session in order to acknowledge its influence upon the hiking technique's performance, studies by Wright, Clarke, Niinima and Shephard (1975) and Spurway and Burns (1993) were found.

Wright et al. (1975) designed a training program for dinghy yachtsmen which included a training circuit, specific strength and resistance exercises and races. The program was carried out for 14 weeks. They took physiological measurements before and after training, which included skin folds, anthropometric observations, muscle strength and resistance, balance, aerobic capacity, simulated hiking technique and anaerobic capacity. Body mass was reduced as was the case with the skin folds, whilst muscle strength and resistance along with anaerobic capacity was increased. Aerobic capacity did not change. There was less of an oxygen debt in order to reach the maximum effort and the yachtsmen also noticed an improvement in fatigue endurance when they used the hiking technique. The yachtsmen achieved better sporting results the following season, but the study contains some important methodological weaknesses from not taking the results presented into consideration, as for example, the fact that there was not a control group to compare the training effects with.

In contrast, Spurway and Burns (1993) concluded that the training sessions that are usually proposed for yachtsmen, including the one designed by Wright et al. (1975), which also tend to include a large general aerobic base and equal resistence or anaerobic work, were a far cry from the training sessions needed by the specific muscles used in the hiking technique. Therefore, they compared the results of 2 specific training sessions in order to improve the technique; one static and one dynamic.

The subjects did 4 tests that were related to the work that the hiking technique entails. They were done both before and after the 8-week training sessions. They were divided into 2 groups, one of which concentrated on the dynamic training sessions and the other on the static type. All of the subjects improved in at least 3 (some in all) of the 4 tests previously mentioned. The group that each subject belonged to was not significantly influential. With regards to the fulfillment and adherence to the training program, it is important to point out that it was greater in the dynamic training sessions whilst the static training sessions turned out to be more effective in terms of the time dedicated to them.

Literature Review

There are very few literature reviews that focus on or even include a section on the hiking technique.

Spurway (2007) made a review of the studies that described the physiology of this technique aiming to corroborate his “Quasi-isometric” concept. From the studies that have been analysed, he concluded that the physiological signs were unambiguous: heart rate was higher than necessary for the oxygen supply, heightened blood pressure (especially dyastolic) and a high degree of hyperventilation. According to Spurway (2007), all of these signs show the isometric profile of the yachtsmen with a high heart rate in order to drive the blood through the active muscles against the heightened intramuscular pressures and also the heightened ventilatory thrust with the need to provide oxygen to the inadequately perfused muscles. Furthermore, he added that there was evidence of a dynamic part of this technique (mostly in the upper body). As a result of this, he proposeed the term “quasi-isometric” as a metabolic description for the hiking action which confirms that there has to be changes in the yachtsmen’s training sessions and they need to add a dynamic element to the already existing static one.

Allen y De Jong (2006) reviewed the medical studies regarding sailing, from which they were able to define some aspects of this sport such as: injuries, improved performance, nutrition and hydration, etc. They included a specific section about the physiology of hiking where they differentiate between the authors who defend the static nature of this technique against those who believe it to be dynamic. Moreover, they define the physical stress of this position, like the contraction of the quadricepts, psoas-iliac and abdominal muscles with the body weight straining the patellofemoral articulation. They also confirm that a bad technique tends to provoke knee pain; when tired, the majority of yachtsmen tend to isolate the vastus lateralis which then leads to patellofemoral pain. On the other hand, they confirm what was stated by Spurway (2007) regarding the need to have a mixed training session, using both dynamic and static exercises in order to improve the hiking technique.

Manzanares et al. (2012) concentrated on reviewing, identifying and analysing the investigations that they had looked into surrounding the influencing factors on sports performance in sailing. On analysing said investigations, they found that many authors defined the hiking technique as one of the influencing factors in performance. They emphasised the work carried out by Shephard (1997) who defended the importance of studying this position from different perspectives. One of the most obvious was correcting one's posture in order to avoid injuries or improve technical performance and therefore, the yachtsman's performance. They also pointed out the interest that many authors had created (Blackburn, 1994; Vangelakoudi et al., 2007) surrounding the knowledge of the produced effort intensity, analysing parameters like VO2, lactate and blood pressure amongst others or blood flow (Cunningham & Hale, 2007) in order to demonstrate that this position is not only static or isometric but also dynamic. Moreover, they make reference to studies that analyse the energetic system involved in the technique (Cunningham & Hale, 2007; Marchetti et al., 1980). The studies have shown that it is almost a completely dynamic movement that the aerobic system uses. This goes against what was previously thought when it was considered a static and anaerobic movement.

Other studies

As well as the categorised studies, there are additional ones which are directly linked with the hiking technique. The majority of them are to do with the development of a sailing ergometer simulation to measure the different variables for each study (Callewart et al, 2013; Gale & Walls, 2000). There are others such as the one carried out by Jansen, Abbema & Howe (2012) where they developed protective shorts consisting of 3 layers: a more rigid central layer to distribute the force of impact, an outer layer that absorbs the force and a comfortable inner layer which comes into contact with the skin. They were compared with the protective shorts that are already on the market and were found to be more comfortable for the yachstmen with similar benefits to those which are already available.

Instruments

On analysing the different studies regarding the hiking technique, each one has investigated different variables depending on the objectives sought. Many instruments have been used in order to measure these variables. In this section is a list of the most used variables in order to analyse the different fields related to the hiking performance.

Regarding physiological responses during the hiking action, many measuring instruments were found in these studies (Table 5) depending on the variable that was to be measured.

TABLE 5
Measuring instruments for physiological variables.

Instrument	Variable
Treadmill	Aerobic capacity
Gas analyser	Respiratory capacity (VO2, CO2)
Lactate analyser	Blood lactate level
Cycloergometer	Aerobic capacity test
Electromyography	Degree of muscle implication
Infrared spectroscope	Muscle blood flow, Tissue oxygenation
Pulsometer	Heart rate
Blood pressure monitor	Blood pressure

In Table 6 the instruments used to measure the biomechanical responses during the hiking action are shown.

TABLE 6
Measuring instruments for biomechanical variables.

Instrument	Variable
Photogrammetry	Spinal column movements
Isokinetic dynamometer	Isokinetic force. Maximum Voluntary Contraction (MVC)
Strain gauge	Sheet and girth force. Maximum Voluntary Contraction (MVC)
Goniometer	Árticulation angles
Force platform	Vessel's CDG calculation

Further to these instruments, one of the main ones used in the majority of the analysed studies was the simulator or the dynamometer where the hiking technique takes place. Many authors have designed their own dynamometer for the study that they carried out. In addition, others have used simulators designed by companies who specialise in the sector.

DISCUSSION AND CONCLUSIONS

After the reading and analysis of the research on the technique of hiking, we can conclude that this technique has a fundamental role in the performance of dinghy sailing with medium and high winds. This technique consists of the sailor, aided by the straps, stretching his body backwards, to a greater or lesser extent depending on the wind strength to counteract the forces exerted by the wind on the sails, which tend to tip the boat. To perform the hiking technique successfully, the competitor must be able to hold this position long enough, which also depends on the wind speed, using his ability to aerobic work due to the dynamic nature of the technique, which forces him to continually make small adjustments in weight and position. In addition, the competitor must possess a strong musculature to endure isometric contractions in both quadriceps muscles (muscles more involved) and the abdomen; hamstrings; lateral, lumbar and paravertebral vast, which are part of the execution of this technique, and lower body joints (ankle, knee and hip) strong enough to withstand the muscle moments that are required.

Given these requirements, note the paucity of studies on training to improve the performance of the hiking technique, which, besides being very old, have major methodological shortcomings that prevent consideration of the results. Therefore, an interesting line of research for the future could be to study the effects of specific training in hiking performance, holding it with current research techniques and a consistent methodology with that study.

REFERENCES

Aagaard, P., Beyer, N., Simonsen, E. B., Larsson, B., Magnusson, S. P. & Kjaer, M. (1998). Isokinetic muscle strength and hiking performance in elite sailors. *Scandinavian Journal of Medicine & Science in Sports, 8,* 138-144.

Aagaard, P., Simonsen, E. B., Beyer, N., Larsson, B., Magnusson, S. P. & Kjaer, M. (1997). Isokinetic muscle strength and capacity for Muscular Knee Joint Stabilization in Elite Sailors. *International Journal of Sports Medicine, 18*, 521 - 525.

Allen, J. B., & De Jong, M. R. (2006). Sailing and sports medicine: a literature review. *British Journal Sports Medicine*, *40*, 587-593. doi: 10.1136/bjsm.2002.001669.

Beillot, J., Rochcongar, P., Gouard, P., Simonet, J., Briend, G. & Le Bars, R. (2001). Le rappel sur Finn: approche biomecanique. *Cinésiologie*, 80, 179-91.

Blackburn, M. (1994). Physiological responses to 90 min of simulated dinghy sailing. *Journal of Sports Sciences*, *12*, 383-390.

Blackburn, M. & Hubinger, L. (1995). Determination of Physiological profiles and exercise training programs for competitive dinghy sailors. *National Sport Research Centre,* 1-16.

Callewaert, M. (2013). Development of an upwind sailing ergometer. *International Journal of Sports Physiology and Performance, 8*, 663-670.

Callewaert, M., Boone, J., Celie, B., De Clercq, D. & Bourgois, J. (2013). Cardiorespiratory and muscular responses to simulated upwind sailing exercises in Optimist. *Pediatric Exercise Science, 26*(1), 56-63

Castagna, O. & Brisswalter, J. (2007). Assessment of energy demand in Laser sailing: influences of exercise duration and performance level. *European Journal of Applied Physiology, 99*, 95–101.

Cunningham, P. & Hale, T. (2007). Physiological responses of elite Laser sailors to 30 minutes. *Journal of Sports Sciences, 25*(10), 1109-1116.

DeVito, G. L., Di Filippo, F. & Marchetti, M. (1993). Hiking mechanics in Laser athletes. *Medical Science Research, 10*(23), 859-61.

Felici, F., Rodio, A., Madaffari, A., Ercolani, L. & Marchetti, M. (1999). The cardiovascular work of competitive dinghy sailing. *Journal of Sports Medicine and Physical Fitness, 39*(4), 309-314.

Gale, T. J., & Walls, J. T. (2000). Development of a sailing dinghy simulator. *Simulation, 74*(3), 167-179.

Jansen, A., Van Abbema, A., & Howe, C. (2012). Improving comfort while hiking in a sailing boat. *Procedia Engineering, 34,* 355 – 360.

Kuen, W., Burnett, A., Xie, W., Wee, P., Lim, J., & Tan, K. (2010). Levels of muscle activation in strength and conditioning exercises and dynamometer hiking in junior sailors. *International Symposium on Biomechanics in Sports, 26*(4), 1066-1075. doi: 10.1519/JSC.0b013e31822e9378

Larsson, B., Beyer, N., Bay, P., Biond, L., Aagaard, P., & Kjaer, M. (1996). Exercise performance in elite male and female sailors. *International Journal of Sport Medicine, 17(*7), 1-5.

Mackie, H. W. (1999). Preliminary assessment of force demands in laser racing. *Journal of Science & Medicine in Sport, 2*(1), 78-85.

Mackie, H., Sanders, R., & Legg, S. (1999). The physical demands of Olympic yacht racing. *Journal of Science and Medicine in Sport, 2*(4), 375-388.

Maisetti, O., Boyas, S. & Guevel, A. (2006). Specific neuromuscular responses of high skilled laser sailors during a multi-joint posture sustained until exhaustion. *International Journal of Sports Medicine, 27*, 968–975.

Maisetti, O., Guevel, A., Iachkine, P., Legros, P., & Briswalter, J. (2002). Sustained hiking position in dinghy sailing. Theorical aspects and methodological considerations for muscle fatigue assessment. *Science & Sports, 17*(5), 234-246.

Manzanares, A., Segado, F., & Menayo, R. (2012). Factores determinantes del rendimiento en vela deportiva: revisión de la literatura. *Ciencia, Cultura y Deporte, 20*(7), 125-134.

Marchetti, M., Figura, F., & Ricci, B. (1980). Biomechanics of two fundamental sailing postures. *Journal of Sport Medicine, (20),* 325-332.

Putnam, C. A. (1979). A mathematical model of hiking positions in a sailing dinghy. *Medicine and Science in Sport, 11*(3), 288-292.

Rodio, A., Madaffari, A., Olmeda, C., Petrone, D. M., & Quattrini, F. M. (1999). Energetic and cardiovascular demand in young sailor (optmist). *Medicina dello Sport, 52*(3), 151-158.

Schütz, G. R., Haupenthal, A., Ruschel, C., Fontana, H. B., Hubert, M., Pereira, S. M., & Roesler, H. (2011). *Portuguese Journal of Sport Sciences, 11*(2), 931-934.

Sekulic, D., Medved, V., Rausavljevi, N., & Medved, V. (2006). EMG analysis of muscle load during simulation of characteristic postures in dinghy sailing. *Journal of Sports Medicine and Physical Fitness, 46*(1), 20-27.

Shephard, R. J. (1997). The biology and medicine of sailing. *Sports Medicine, 23*(6), 350-356.

Sprada, F., Schütz, G. R., Cerutti, P. R., Calado, L. Brito, H., & Roes, H. (2007). Biomechanical analysis of spine movements in hiking on sailing. *XXV ISBS Sym posium 2007, Ouro Preto – Brazil.*

Spurway, N. C. (2006). Hiking physiology and the quasi-isometric concept. *Journal of Sports Sciences, 25*(10), 1081 – 1093.

Spurway, N. C., & Burns, R. (1993). Comparision of dynamic and static fitness. *Medical Science Research, 21(*23), 865-867.

Spurway, N. C., Legg, S., & Hale, T. (2007). Sailing Physiology. *Journal of Sports Science, 25(*10), 1073-1075. doi: 10.1080/02640410601165171.

Tan, B., Aziz, A. R., Spurway, N. C., Toh, C., Mackie, H., Xie, W., Wong, J., Fuss, F. K., & Teh, K.C. (2006). Indicators of maximal hiking performance in Laser sailors. *European Journal of Applied Physiology, 98*, 169–176.

Vangelakoudi, A., Vogiatzis, I., & Geladas, N. (2007). Anaerobic capacity, isometric endurance and Laser sailing performance. *Journal of Sports Sciences, 25*(10), 1095-1100

Vogiatzis, I., Andrianopoulos, V., Louvaris, Z., Cherouveim, M., Spetsioti, S., Vasilopoulou, M., & Athanasopoulos, D. (2011). Quadriceps muscle blood flow and oxygen availability during repetitive bouts of isometric exercise in simulated sailing. *Journal of Sports Sciences, 29*(10), 1041-1049.

Vogiatzis, I., Spurway, N. C., Jennett, S., Wilson, J. & Sinclair, J. (1996). Changes in ventilation related to changes in electromyograph activity during repetitive bouts of isometric exercise in simulated. *European Journal of Applied Physiology and Occupational Physiology*, *72*(3), 195-203.

Vogiatzis, I., Tzineris, D., Athanasopoulos, D., Georgiadou, O., & Geladas, N. (2008). Quadriceps oxygenation during isometric exercise in sailing. *International Journal of Sports Medicine, 29*, 11–15

Wright, G., Clarke, J., Niinimaa, V., & Shepard, R. J. (1976). Some reactions to a dry-land training programme for dinghy sailors. *British Journal of Sports Medicine*, *10*, 4-10.