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THE EFFECT OF A CORE STABILITY EXERCISE ON SURF SPRINT PADDLING PERFORMANCE

Master's Thesis

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Abstract:

The science applied to surfing suggests the suitability of including physiotherapy in training, which attempts new insights on current knowledge in this area and thus enrich sports science by a multidisciplinary approach. The primary purpose of this study was to investigate the effects of a core stability exercise on surf sprint paddling performance.

The sprint paddling test was performed in the ocean and analysed with a fluid flow sensor (Riedel Communication, R&D Hub PT, Germany). Five physical tests, based on sport-specific demands of paddling, were another evaluation tool. Both were tested before and after the intervention. It consisted of two dependent physiotherapy-based training units, which were held twice a week for one month.

Regarding the effect, the postural stability was improved; however, the velocity-related variables were not. Statistically, significant improvement appeared in some of the physical tests only in some groups, while the performance of the Closed Kinetic Chain Upper Extremity Stability Test was significantly improved in all measured groups.

In terms of the variables, we observed, completing core stability training has the potential to improve surf sprint paddling performance, thus contributing to the general development of surfers.

Keywords: trunk stabilisation, sports periodisation, aquatic evaluation, surf sprint paddling

Jméno a příjmení autora: Vít Musil

Název: Vliv stabilizačního cvičení trupu na výkon při surfovém pádlování ve sprintu

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Abstrakt:

Současná věda zkoumající surfování naznačuje vhodnost zapojení fyzioterapie do tréninku, která přináší nové pohledy na stav poznání v této oblasti a obohacuje sportovní vědu o multidisciplinární přístup. Hlavním záměrem této práce bylo zhodnotit efekt stabilizačního cvičení na výkon při surfovém pádlování ve sprintu.

Pádlovací test byl proveden v oceánu a analyzován „fluid flow“ senzorem (Riedel Communication, R&D Hub PT, Německo). Dalšími nástroji pro hodnocení efektu intervence bylo pět fyzických testů, založených na specifických požadavcích pádlování ve sprintu. Oba druhy hodnocení byly provedeny před a po fyzioterapeutické intervenci. Ta se skládala ze dvou závislých tréninkových jednotek, které probíhaly dvakrát týdně po dobu jednoho měsíce.

Pokud jde o účinek, došlo u surfařů ke zlepšení posturální stability. Proměnné související s rychlostí však zůstaly beze změny. K statisticky významnému zlepšení došlo u některých fyzických testů, ale pouze v určitých skupinách, zatímco u testu stability horních končetin v uzavřeném kinetické řetězci došlo ke zlepšení u všech sledovaných skupin.

S ohledem na výsledky soudíme, že absolvováním tréninku zaměřeného na stabilizaci trupu lze zlepšit výkon při surfovém pádlování ve sprintu, a tím přispět k obecnému rozvoji surfařů.

Klíčová slova: stabilizace trupu, periodizace tréninku, hodnocení ve vodě, surf sprint paddling

I declare that I have prepared the diploma thesis independently under the guidance of Zdeněk Svoboda, Ph. D. and Márcio Borgonovo dos Santos, Ph. D. In my work, I followed the principles of scientific ethics, all used literary and professional sources.

Olomouc, 29.11.2021 …………………………………

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Dedicated to my future daughter…

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LIST OF USED ABBREVIATIONS

ASIA = American Spinal Injury Association

CKCUEST = Closed Kinetic Chain Upper Extremity Stability Test

COPD = Chronic Obstruction Pulmonary Disorder

IF = International Federation

IAP = Intra–abdominal pressure

IOC = International Olympic Committee

ISA = International Surfing Association

KPI = Key Performance Indicator

MOV = Maintaining Optimal Velocity

MPUT = Modified push-up test

OAP = Overall Performance

OLST = One-leg stand test

PNF = Proprioceptive Neuromuscular Facilitation

ROV = Reaching optimal velocity

SIAS = Spina iliaca anterior superior

SMBT = Seated medicine ball throw

SUT = Sit-Ups Test

TLT = Trunk Lift Test

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1 INTRODUCTION

The popularity of wave surfing all around the world has been on the rise in recent years. In 2002, the surfing population was around 13 million; since then, the number tripled to 37 million as reported in 2013 (Furness, Schram, et al., 2018). Taking into account the outstanding year 2016, in which the International Olympic Committee (IOC) recognized surfing as a new aquatic sport for the Summer Olympic Games in Tokyo 2021, the sensation persists with the adoption of surfing at the Paris 2024 Olympics (IOC, 2017; IOC, 2020a). As IOC stated, every Olympic sport has to be governed by International Federation (IF), which oversees its sports competitions. While IFs are independent and autonomous, those seeking IOC recognition must ensure that their statutes and activities conform with the Olympic Charter (IOC, 2020b). Furthermore, International Surfing Association (ISA) launched the Athlete's commission to ensure the interests and views of the global community of surfers are appropriately represented within the IF. To those, IOC provides direct financial support through the distribution of Olympic Games revenues, the IF Development Programme and other Games–specific support programmes, enabling them to operate, govern, develop and promote their sports worldwide. Mutual collaboration between these bodies is beneficial in planning future Games, development, sustainability, and gender equality in surfing (IOC, 2020a). As can be expected, the acceptability of surfing will also lead to the creation better background within a professional team, where other professions would newly find their places (Magee et al., 2010).

Such a specialist should be able to serve individually tailored training programmes providing comprehensive care. For this consequence, it is important not only for coaches, but also for other team specialists to have deep knowledge in aquatic locomotion. Initiating forward movement is highly dependent on the surfer's ability to overcome and reduce the resistance acting on the loaded surfboard submerged in water. By taking appropriate body positions on the board together with moving arms, by pushing and pulling the water backwards, helps to convert muscle energy into kinetic energy, to create propulsion through the aquatic environment (Lauer et al., 2016). Propulsion is influenced by salinity (Cullum et al., 2016), surfboard buoyancy, drag (Borgonovo-Santos, Zacca, et al., 2021), technique (Sheppard et al., 2013) and occurs as a result of paddling, followed by take-off execution surfer getting into the vertical position and riding the wave (Secomb et al., 2015b). Paddling is the most time–consuming activity on the water and the most important feature of competitive success (Sheppard et al., 2013). Although competitive surfers paddle for 50.9 % (Minghelli et al., 2019), in recreational surfers, it was 44 % of total time spent in water (Meir et al., 1991). Secomb et al. (2015b) reported 46.7 % of time also in competitive surfers, but furthermore distinguished between endurance paddling (return to the line-up), general paddling, and sprint paddling.

The art of paddling is crucial for the surfer's success in the water. This skill is performed in the prone position on the surfboard using mainly upper limbs and it needs to be developed on several levels (Mendez-Villanueva & Bishop, 2005). Surfer's paddling performance results in improved positioning in the line–up and brings subsequent advantages, e. g. sitting deeper on the peak, receiving the first choice of wave and ability to enter faster (Secomb et al., 2015b). Sprint paddling accounts for the smallest percentage of paddling activity and requires the greatest level of upper extremity strength and power to catch a wave successfully. Well-positioned surfer in the line–up, with the approaching wave, performs several powerful arm strokes ensuring that speed combined with the use of wave slope and gravity allows the surfer to enter the wave (Coyne et al., 2017). Time spent riding the wave depends on correct relocation around the line–up and specifically the surfer's strategy (Lowdon et al., 1996). Same level of importance is being given to strategy outside the water, whether a surfer decides about physical preparation for surfing individually or is guided by a specialist. Combination and practising of complex skills, such as postural control, balance or coordination, improves paddling performance in competitive and recreational surfers (Axel et al., 2018; Coyne et al., 2017; Mendez-Villanueva & Bishop, 2005).

Similar to other sports, if the specific physical skills of surfing are not trained for, proficiency of tactical and technical factors related to successful performance will be reduced (Secomb et al., 2015a). The lack of scientific information about core stability training in surfing and the widespread monodisciplinary approach to understanding sport performance is recognizable. This fact led us to use a multidisciplinary approach, which brings together knowledge of conditioning and physical therapy. Based on the literature, we are suggesting implementation of core stabilization as a complement to surf training, in order to improve sprint paddling performance (Frank et al., 2013; Piggott et al., 2020).

2 LITERATURE REVIEW

2.1 SURFING HISTORY

Surfing is being an ancient sport with scant, written or recorded history. The beginnings of the sport in the form of canoe surfing appear to date to almost 2000 B.C., when the ancestors of the Polynesians and other Pacific Islanders started moving eastward from Southeast Asia (Finney & Houston, 1996). Surfing as we know it today is a Polynesian invention, with Hawaii's population mastering the art of standing on and shaping surfboards around 1000 years ago with both royalty and commoners practising the sport (Warshaw, 2017). Afterwards, when Europeans discovered Maori tribes surfing the waves, the sport was adopted and brought to Portugal, wherein surfers were filmed for the first time (Mendez-Villanueva & Bishop, 2005).

Indigenous surfing in the Pacific was most developed on the islands within the Polynesian triangle, bounded by Hawaii, Easter Island, and New Zealand. Early reports of surfing along the shores of islands from Papua New Guinea to Polynesia indicate that surfing, in its rudimentary form, was part of the common heritage of those who spread across the Pacific thousands of years ago. Polynesians called it *papa he 'e nalu* (papa: daddy, *he 'e:* ride; *nalu:* surf). Surfing was noble, and commoners would take their rightful place on smaller boards, but never at the same time as their chiefly leaders who sometimes surfed wearing their massive feathered headdresses and ceremonial cloaks. Surfing was not merely a pastime for the leaders of the old. This sport served as a training exercise to keep the chiefs in top physical condition. Furthermore, surfing also served as a system of conflict resolution (Finney & Houston, 1996; Nendel, 2009).

2.1.1. Surfing in Polynesia

British explorer Captain James Cook was one of the first to describe the act of surfing following a visit to the Tahitian Islands in 1777. After seeing a canoe surfer, Cook's surgeon, William Anderson, commented: 'He was carried along at the same rapid rate as the wave, until it landed him on the beach. Then he went searching for another swell. I couldn't help concluding that this man felt the greatest pleasure while driving so fast and so smoothly by the sea. ' (Warshaw, 2017, p. 49). On a subsequent visit to Hawaii, after Cook's death, Lieutenant James King wrote an entry in Volume III of the *Voyage* series in 1779 about the 'great art' of stand-up surfing, seen in Hawaii (Farley, 2011).

Because the Hawaiian Islands were isolated for many centuries from western outlanders, Cook's discovery of islands had a great impact on surfing development. The immune system of the original inhabitants was not defenceless against various germs, pathogens, and viruses brought about by the first Westerners. Natives were cut down by cholera, typhoid, tuberculosis, measles, flu, mumps, smallpox, scarlet fever, dengue fever, leprosy, and venereal disease. At the time of Cook's arrival, according to estimates, there were four hundred thousand Hawaiians on the islands. By 1896, the number had been reduced to just over thirty thousand. Hawaii was reshaped by more than these terrible new diseases. Native custom and culture were also under attack, particularly with the arrival of American missionaries in 1819. Fewer than 160 Protestant missionaries lived in Hawaii, and none served in an official law-making capacity. But its influence on island policy and culture was so immediate and significant that islanders soon made reference to the 'missionary monarchy'. Protestantism briefly became the nation's religion and a new code of missionary-backed laws and decrees was passed. Surfing was described by one of the original missionaries in 1820 as the pastime of 'chattering savages', representing 'destitution, degradation, and barbarism'. Hula dancing was banned and surfing was influenced by 'blue laws' against gambling and nudity. Taking away sex and wagering, and all of sudden the whole thing was much less attractive to most natives. A report from 1852 says that the sport was 'rapidly passing out of existence', and another from 1876 notes that surfing was 'fast dying out'. By 1890, however, the worst was over. The Hawaiian immune system had been strengthened. The missionaries were long gone. The sport entered a quiet but sustaining period, almost a second incubation, that lasted just a few years. Despite few changes in technique, board design, or the number of participants, sport and its practitioners reemerged looking different somehow, at least for the world at large. Shortly after the early twentieth century, the swashbuckling writer Jack London reintroduced surfing as nothing less than 'a royal sport for the natural kings of the earth' (Warshaw, 2017).

The turn of the twentieth century saw the annexation of Hawaii to the United States of America as a territory. The meaning of surfing changed drastically from a sport steeped in cultural and religious significance to one resembling the same competitive and commercial values of other American sports, such as baseball, football, and basketball; the transformation over this period altered the sport, leading to the development of modern surfing (Nendel, 2009).

2.1.2. New Zealand discovery

When Europeans arrived in New Zealand, they found that coastal Maori tribes were 'surfing' (whakaheke ngaru) using relatively uncrafted boards (kopapa), logs (paparewa), canoes (waka) and even kelp bags (poha) as a regular summer activity. A similar situation was observed in the mid 1800s, after the arrival of the missionaries. The advent of Christianity meant that many aquatic activities practised by the Maori were no longer deemed to be appropriate, so the practice of surfing waned (Williamson, 2000). The sport of surfing underwent numerous changes over this period; with these changes came reduced links with its traditional values. With the rebirth of surfing in Hawaii taking place in the early twentieth century, an extraordinary man named Duke Paoa Kahanamoku, the three-time world record holder and multiple Olympic gold medal champion in free-style swimming, embarked on a world tour. He visited Wellington, New Zealand, in 1915 for a swimming demonstration at Lyall Bay; furthermore, he also demonstrated surfing. Afterwards, as a devoted traveller, he spent a lot of his time all over Europe, Australia, and the USA performing surfing and swimming demonstrations. Since then, the popularity of surfing has been gradually growing, becoming a thriving culture in the 21st century (Mendez-Villanueva & Bishop, 2005).

2.2 SURFING TERMINOLOGY

Surfing, as an activity, has been romantically narrated by novelists as the growth in the 20th century evolved in creating a new culture (Finney & Houston, 1996; Warshaw, 2017; Williamson, 2000). Growing interests can be explained multifactorial, as the benefits of coastal life, blue, and other perceptions experienced in the marine environment have already been demonstrated (Hunter & Stoodley, 2021). Surfing research is very scarce, one of the first scientific articles (Lowdon et al., 1989, p. 7) describes surfing as follows: 'Modern surfboard riding has been described as involving prone endurance paddling to reach the take-off area, high energy expenditure in paddling to catch a wave, and a variety of intense energy standing manoeuvres to keep the surfboard close to the curling wave for optimum speed and excitement.' Although the definition of scientists from the near past reports similarly: 'The surfing action is to ride a surf craft along the unbroken section or wall of a wave, as it inches closer toward the shore' (Mendez-Villanueva & Bishop, 2005, p. 56) or other by Loveless and Minahan (2010a, p. 407): "The activity of surfing can be described as the action of an individual riding a floating vessel on the broken or unbroken section of a wave, as it moves towards the shore." Finally, the current articles no longer use a general description of the activity. As the growing interest in surfing science has been recorded, past 5 years scientists provide more specific information about surfing, which is more closely related to the research topic (Langenberg et al., 2021; Nessler et al., 2019; Parsonage et al., 2020).

2.2.1. Surfing glossary

For better understanding and unification of the terms used, a compiling glossary is provided to explain the jargon of surfers (Anonymous, 2013; *Glossary of surfing*, 2021).

2.2.1.1. Surfboard

The essential equipment for a surfer is an adequate surfboard. To determine the type of board, it must be decided about surfing experience (Farley, Abbiss, et al., 2016), anthropometric information (Fernandez–Gamboa et al., 2017), or actual swell conditions (Coyne et al., 2017) that are closely related to surfing style.

Blank - usually a polyurethane foam core that comes in different basic designs and rockers depending on the length and type of surfboard being shaped.

Bottom contour - the lateral curve of the bottom of the board as it runs from rail to rail. The shape of the bottom might be flat, convex, or concave.

Carbon fibre - a type of super-strong fibre that soaks in resin, is occasionally laid in strips along the length, rails, or tails of a board during glassing to prevent creasing.

Channels - the channel surfboard bottom consists of flat planes that are designed in a concave configuration. Since the channels are side by side, the water is not compressed like it is in a full concave, and each channel propels water down the underbelly of the surfboard and converts it into forwarding thrust.

Concave - the main purpose of this shape is to channel the water flow down the length of the surfboard. The water flow along the centre and out through the tail facilitates the lift and responsiveness to the surfboard, which is important for critical turns.

Drag - the effect that causes water flow to be slowed or disrupted as it passes along bottom surface. Controlled drag is an essential requirement of surfboard manufacturing.

Drive - the result of water pressure pushing up against the bottom surface of a surfboard, causing acceleration down the face of a wave – a key factor for control and direction defined by the settings of the fins.

Epoxy - a type of plastic resin used by some manufacturers in place of polyester, known for its durability.

Foil - foam distribution along the surfboard is an important factor for correct flow through the water. Excessive volume of the foam around nose, centre, or tail will create uneven flow, which results in an unbalanced surfboard.

Rails - the perimeter of the board determine the velocity and manoeuvrability. There are several types of rails, and each represents a different effect. Soft, rounded rails cause slower ride but are easier to handle, while down rails increase speed but make the board more difficult to turn.

Release - the effect that allows water flow to accelerate as it passes along the surfaces of a surfboard. The release is altered through the tail rocker, outline curves, trailing fin edges, and through bottom features such as concaves and channels.

Rocker - the curve of the surfboard from nose to tail.

Tail - the shape of the back section of the board is crucial to determine how a surfboard will function. The **pin tail** shape is typical for its sharp pinpoint converging to the tail and optimally functions in large waves due to the minimal surface area. The other option is a **round tail** with more surface area, allowing smooth turns in mid-range surf. Surfers using a tail with a **square shape** can experience speedy surfing; the edges of this surfboard are sharp and rectangular. The opposite **squash tail**, a shortboard clamp, reacts differently thanks to a square tail with rounded edges, which softens the feeling and reduces the response. Finally, the swallow tails excel in maximum propulsion combined with manoeuvrability, due to the shape of the letter V cut into the stringer.

2.2.1.2. About the water

Beach break - an area where the waves break just off a beach or over a sandbar further out from the shore.

Crest - the top section of the wave, or peak just before the wave break.

Line-up - the queue area where most surfers are positioned in order to catch a wave.

Set of waves - a group of larger waves coming within the swell.

Swell - a series of waves that have travelled from their source and that will start to break once the swell reaches shallow water.

Wall - the wave section is where the wave has not broken and where the surfer manoeuvres to ride the wave.

2.2.1.3. The most common techniques and manoeuvres

Aerial - navigating the surfboard briefly into the air and landing back upon the wave to continue the ride.

Drop-in - engaging the wave.

Duck–dive - a manoeuvre used to overcome waves instead of riding.

Floater - riding up on the top of the breaking part of the wave and dropping down to the wall.

Goofy - riding with the right foot in front.

Pop–up - taking off from the prone position to vertical position, predominantly in one jump.

Regular - riding with the left foot in front.

Snap - a quick, sharp turn of the top of the wave.

Tube-riding - riding inside the hollow curl of a wave.

Wipeout - one being thrown off the surfboard by a wave.

2.3 THE ACTIVITY PROFILE OF SURFERS

Performance analysis incorporates several applications, including tactical and technical evaluation, analysis of movement and physical demands, and the development of predictive models. Coaches and sport scientists can now collect objective data on athlete work rates through heart rate monitors or spirometry, evaluate training loads, movement patterns, and activity profiles of athletes through global positioning system units, and track athletes through time-motion analysis (Borgonovo-Santos, Zacca, et al., 2021; Farley et al., 2012). Meir et al. (1991) examined recreational surfers for 1 hour, reporting that 44% of the total time was spent on paddling, 35% stationary, 5% wave riding, and 16% miscellaneous activity. More recently, world-class professional surfers were investigated during competitive heats (Mendez-Villanueva et al., 2006) in which surfers spent 51% of the paddling, 42% stationary, 3.8% wave riding, and 2.5% performing miscellaneous activities. For purposes of these studies, activities were defined as presented in Table 1 (Meir et al., 1991).

Table 1. Defining surfing activities (Meir et al., 1991)

paddling	All forward board propulsion using alternate arm–paddling action.
stationary	Subject sitting or lying on their board, including a slow 1 arm paddling action to maintain the position in take–off zone.
wave riding	Recorded from the time of a subject's last arm stroke to the moment the subject's feet lost contact with the board or the subject effectively finished riding the wave.
miscellaneous activities	Walking or running up the beach, wading, duck diving under white water, and recovering and getting back on the surfboard after falling.

The newly published articles modified the previous version of the definition and divided activities based on similar energy expenditure, as shown in Table 2 (Secomb et al., 2015b). Two-hour motion analysis of competitive surfers revealed that paddling consumed 42.6%, sprint paddling 4.1%, stationary position 52.8%, wave riding 2.5%, and recovery 2.1% of total time (Secomb et al., 2015b). Likewise, Minghelli et al. (2019) reported comparable results for Portuguese competitors. Athletes spent on paddling 50.9%, sprint paddling 1.9%, stationary position 34.1% , wave riding 3.7%, and participation in miscellaneous activities (e.g., duck diving, board recovery, etc.) 9.4% of the total time. In summary, the values can vary depending on the surfing conditions, such as weather, location and time of year (Santos et al., 2019). Accepting this fact, it might be concluded that paddling, as an activity, is one of the most time-consuming parts of surfing. Without technical proficiency and physiological fitness in paddling, the surfer might have difficulties in reaching the correct position in order to catch the most appropriate waves.

Table 2. Updated division of surfing activities (Secomb et al., 2015b)

paddling	The propulsion of the surfboard in a forward through the use of the cyclic movement of arms.
paddling to return to the line-up	Total time required for the surfer to return to the line-up through performing paddling after wave riding. The time was recorded from the first alternate-arm stroke after the participant assumed a prone position on the surfboard to the completion of the last alternate-arm stroke when the participant relocated to the line-up.
sprint paddle for a wave	Total time from the first "aggressive" alternate-arm stroke, in the direction of an approaching wave, to the last alternate-arm stroke preceding wave riding, or the completion of "all out" paddling.
general paddling in the line-up	Total time from the first alternate-arm stroke to the last, before the participant either began to sprint paddle for wave or remain stationary. This activity required the participant to be already in the line-up zone.
stationary	Any occurrence the participant was either lying prone on the surfboard and not performing any alternate-arm stroke or sitting on the board.
wave riding	The total time from the participant initiating the "pop-up" to either riding off the back of the wave or losing the contact with the surfboard.
recovery of the surfboard	The total time from the participant losing contact with the surfboard to assuming the position of lying prone or sitting on the surfboard.

2.3.1. Sprint paddling performance

Despite the fact that sprint paddling takes less than 5% of the total surfing time, the scientific community considers this activity to be the most crucial (Coyne et al., 2016; Minghelli et al., 2019; Secomb et al., 2015b). In addition, it appears to be an important aspect of a surfing competition. Higher paddling velocity enables surfers to gain a positional advantage over other competitors during a heat and ensures fast entry speed into waves, enhancing the opportunity for the execution of a greater number of manoeuvres that will increase chances to persuade the judges. This has been reinforced by studies that demonstrate that competitive adult surfers are superior in sprint paddling compared to competitive junior surfers (Coyne et al., 2016; Sheppard et al., 2012) and additionally a comparison of both genders (Secomb et al., 2013). Regardless of the level or sex, aquatic locomotion is ensured by alternating left and right strokes while maintaining a pronated position on the board and is the only option to access the surf break, move into position to catch waves, and create enough propulsion force to paddle into the wave itself, neglecting tow–in surfing. Among the main factors influencing the paddling performance are technical adjustments, such as stroke length, chest position, and arm recovery (Sheppard et al., 2013). Considering physical preparation, sprint interval training (Farley, Secomb, et al., 2016) and maximal strength training, performing pull–ups and dips, improved sprint paddling performance in competitive and recreational surfers (Coyne et al., 2017). Ultimately, surfing paddling has received little attention in scientific research (Loveless & Minahan, 2010b), so the goal of the current work follows scientific attitudes towards the importance of sprint paddling, as it was decided to evaluate the stability of the core during all-out paddling.

2.4 SURFING INJURIES

Surfing injuries are among the most commonly investigated topics in surfing scientific research. Exploring the knowledge of this field is crucial, as health care providers and coaches may be able to prepare adequate preparation for surfing athletes (Furness et al., 2015; Hanchard et al., 2021b; Nathanson et al., 2002). Not only competitive surfers are at risk of injury but also recreational surfers reported to appear as a critical group (McArthur et al., 2020). Competitive athletes show their skills in various disciplines. Each has its own specifics in terms of the possible risk of injury. To illustrate a different situation, big wave surfers of the last century were able to paddle into waves as high as 7 meters; nowadays, with the assistance of jet skis, tow-in surfers began to tackle 25-meter waves. The incidence of injuries under these conditions is expected to be higher not only due to the speed achieved, but also due to mechanical stress when hitting the water as a result of the wipe-out (Nathanson, 2020). In high-performance, middle-size waves surfing judges evaluate mainly innovative and progressive manoeuvres or their combination, so the highest risk of injury seems to appear when landing aerial manoeuvre. Lundgren et al. (2016) observations further corroborate the epidemiological study of Furness et al. (2015), where the authors revealed significantly higher number of knee injuries. In general, there were fewer acute injury incidents in recreational surfers. Those might suffer from various conditions, not estimating one's own abilities, not respecting rules in the line-up, unergonomic paddling stroke, or inordinate muscle activity (Atencio et al., 2021; Borgonovo dos Santos, 2018; Gandhi et al., 2021). To sum up, the sport of surfing has diversified in surfing environment, equipment, and style, including big wave surfing, high-performance surfing with aerial manoeuvres, which all present their unique thrills and hazards to those participating (McArthur et al., 2020).

2.4.1. Acute surfing injuries

Although early studies focused on monitoring and collecting data on injuries, recent scientific research explores the area of severity, location, type, and mechanism of acute injuries. Granted, that surfing scientists will set up a criterion on training improvements or for protective gear implementation (Furness et al., 2015; McArthur et al., 2020; Nathanson, 2020; Nathanson et al., 2007). So far, research on acute surfing injuries has been limited to the inconsistency of the methodologies used, as the researchers' backgrounds differ. In the prospective study of Nathanson et al. (2007), researchers with medical background collected data on-site during competitive contests over a period of 7 years. Similarly, scientists with an identical focus conducted a study over 12 years using a national database of injuries presented to emergency departments around the United States. While a physiotherapist, Furness et al. (2015) used an online survey using an open-source survey application with responses collection over a period of one year.

To illustrate, the resulting findings are summarized as follows. Nathanson et al. (2007) established risk factors for injury occurrence. Mostly professionals surfing high waves on beaches with rocky or reef seabed are at increased risk of injury, rather than amateurs surfing small waves on sandy beaches. Surprisingly, this fact about status contrasts with Furness et al. (2015) since their findings of incidence rate are slightly higher in recreational surfers. In addition, Nathanson et al. (2007) published an interesting comparison with other sports in which surfing appeared to be less dangerous than men's college basketball but more dangerous than snowboarding. Taking into account the type, location and severity, the same authors revealed that sprains and strains were the most common, followed by lacerations, contusions, and fractures. Unfortunately, Nathanson et al. (2007) did not provide full details on the type of injury. Furness et al. (2015) therefore provide a better description to specify and define the terminology used. In addition to that, the region most injured is the lower extremity (Klick et al., 2016; Nathanson et al., 2007). These findings are in line with those of Furness et al. (2015), who additionally divided the low extremity into subregions, such as hip, knee, shin/calves, or ankle. Furthermore, as part of their study, the authors discussed the severity of the injuries. Most injuries were severe, which was defined as an injury that required the surfer to seek medical treatment and/or be unable to work or surf for at least 1 day. And finally, the mechanism involved in the injury. Nathanson et al. (2007) results are comparable to those obtained by Furness et al. (2015). Most of the injury are caused by direct contact (e.g. struck by own or others surfboard, strike the seabed or surface of the sea). Also in their ground-breaking paper, Furness et al. (2015) linked data on the mechanism and location of injuries. In summary, acute surfing injuries are common with an incidence rate of 1.15 - 6.6/1000 hours but rarely serious. However, it is important to pay sufficient attention to them, as it is believed that neglected rehabilitation can predispose a person to re-injury in the same place (Furness et al., 2014; Furness et al., 2015; Klick et al., 2016; Nathanson et al., 2007).

2.4.2. Chronic and gradual-onset surfing injuries

Early work in this area focused primarily on the incidence, type, location, severity, and mechanism of acute injuries. However, recently published works also consider it important to focus on topics related to chronic injuries or gradually evolving injuries (Furness et al., 2014;

Hanchard et al., 2021b; Nathanson et al., 2002). First, it is considered essential to define the terminology used. Chronic injuries are defined as persistent or episodic pain lasting more than three months. In a recently published article by McArthur et al. (2020), the authors adopt another perspective, claiming that the mentioned terminology is not valid. Instead of the term 'chronic', the term 'gradual onset' of the injury should be used. In this case, the gradual onset of the injury could have been subdivided into acute (have become apparent only recently) and chronic (long-standing) injury. The word 'acute' in this sense does not have the same meaning as in the previous chapter. Since the authors cited used an adjective acute instead of traumatic. However, it is important to consider all types of injuries regardless of terminology. It is believed that primary, secondary, and tertiary prevention provided by the rehabilitation specialist induces the risk of injury (Furness et al., 2014; Pascal & Kevin, 2020).

To illustrate, the results of the articles used describe the most common injuries that persist over a long period of time, with respect to location, mechanism, and type. Early findings on the current topic led scientists to closely discuss the epidemiology of surfing injuries (Furness et al., 2014; Nathanson et al., 2002; Remnant et al., 2020). The pioneering work by Nathanson et al. (2002) conducted an internet-based, multiple-choice survey and figured out that the most common were overuse syndromes resulting in musculoskeletal injuries to the upper extremity and paraspinous muscles. In addition, shoulder strain, back strain, and neck strain were frequently cited. An interesting not surprising fact appeared in athletes surfing more than 20 years. The results showed a significantly higher rate of shoulder strain injury. Nathanson et al. (2002) findings on type and locality are consistent with those obtained by Furness et al. (2014), who designed a more advanced survey explaining the mechanism of injury combined with localization. In their work, the authors provide a detailed analysis of activities that a surfer can perform in the water. The most critical activity is prolonged paddling because the surfer lies in a prone position with hyperextension of the back and, at the same time, rhythmically moves his arms (Furness et al., 2014; Hanchard et al., 2021b). Furthermore, Remnant et al. (2020) reached similar conclusions in their epidemiological study. In summary, chronic injury research is inconsistent with the terminology used. Despite this, it provides important information on incidental injuries that could help establish better injury management and prevention (Furness et al., 2014; Hanchard et al., 2021b; Nathanson et al., 2002; Remnant et al., 2020).

2.4.2.1 Surfer's myelopathy

Surfer's myelopathy is a rare, acute and atraumatic myelopathy that occurs in novice surfers (Freedman et al., 2015). There is a disagreement between the injury definition presented by Remnant et al. (2020) and Freedman et al. (2015). The former would label the surfer's myelopathy as an injury with a gradual acute onset of symptoms. To date, research on surfers' myelopathy has mainly focused on case studies, as it was essential to describe better the accompanying symptoms, potential risk factors, and the mechanism of the injury (Alva-Díaz et al., 2021; Freedman et al., 2015; Gandhi et al., 2021; Thompson et al., 2004). Firstly, the study by Thompson et al. (2004) has shed more light on the discussed issue as he described nine case studies in detail. More current research in 2016 reported 64 cases, while in 2021, it is already 104 (Alva-Díaz et al., 2021; Freedman et al., 2015). Interestingly, the number of cases is growing exponentially, similar to the surfing population (Gandhi et al., 2021; Hanchard et al., 2021b). Surfer's myelopathy is considered a neurological injury because the accentuation of symptoms are most closely related to ischemic disease. For this reason, professionals are using the American Spinal Injury Association (ASIA) designed questionnaire to classify severity. Furthermore, based on the ASIA scale, health care providers can indicate an intensive rehabilitation protocol to improve the patient's prognosis (Freedman et al., 2015). In summary, a surfer's myelopathy is not always a serious health risk for novice surfers, as the full recovery has been widely reported. However, it is necessary to provide education informing trainers about ergonomic possibilities while waiting for the wave or special training programs focused on strengthening the core muscles that stabilize the spine during surfing-related manoeuvres (Alva-Díaz et al., 2021; Freedman et al., 2015; Gandhi et al., 2021; Thompson et al., 2004).

2.4.2.2. Surfer's shoulder

Chronic shoulder complaints are frequently reported among professional and recreational surfers, as proven by epidemiological studies (Furness et al., 2014; McBride & Fisher, 2012; Remnant et al., 2020). The terminology differs, as Remnant et al. (2020) would categorize this condition as gradual chronic onset. Next, considering the activity profile, surfers spend most of the time in the water paddling while assuming a prone position (Minghelli et al., 2019). For the purpose of paddling athletes, repetitively and synchronically rotates with arms in order to gain velocity to catch a wave. The study by Nessler et al. (2019) offers an electromyographic analysis of a single paddling stroke with the following findings. Internal rotators, such as the latissimus dorsi or pectoralis major, are involved primarily throughout the pushing phase of paddling. Likewise, Furness, Schram, et al. (2018) supported this fact in their study on shoulder strength profiling with dynamometer use. The authors reported that internal rotation strength was greater than external rotation strength bilaterally. Further, that external rotation strength was weaker on the non-dominant arm compared with the dominant arm. Previous findings underline the fact that internal rotators are the main muscles involved in paddling and thus cause muscle imbalance between shoulder rotators (Furness, Schram, et al., 2018; Madeira et al., 2019). Consequently, this stress can lead to shoulder impingement, tendonitis, or scapula winging during shoulder abduction (Langenberg et al., 2021).

To conclude, the incidence of injuries between recreational and competitive surfers suggests that surfing is categorized as a medium–risk sport. But due to the recent summer Olympic Games with a debut in surfing, an increase is expected not only in the participants, but also in the number of accidents reported as minor or major injuries. Therefore, it should be in the best interests of surfing specialists to update methodologies not only to reduce injury rates but also to improve load adaptation (Cope et al., 2019; Furness et al., 2014; IOC, 2020a; Pol et al., 2020; Remnant et al., 2020).

2.5 SPORT RELATED MOTOR BEHAVIOUR

Human performance is predefined by individual motor behaviour. Motor behaviour is the study of how motor skills are learned, controlled, and developed to help people practice and experience sports activity. Applications often focus on what to practice, how, and how much. Its knowledge guides us to provide better conditions for learning and practice, as well as to understand why some cues and feedback are better than others. A basic overview of this branch should be essential for anyone who teaches motor skills, including coaches and physical therapists (Knudson & Hoffman, 2018).

Motor development is one of the three main factors involved in motor behaviour. Recent findings on this topic have led to the opinion that the early stages of human development are important for later skills acquisition. However, the development of motor behaviour bridges the entire lifespan from the first fetal movement to the last dying breath (Adolph & Franchak, 2017). Previous findings are in line with those of Vařeka (2021), who supports theory the of dynamic systems as a possible way to explain human motor development. With respect to this concept, the act of surfing tends to happen also in a dynamically fluctuating environment. Hence, it should be appropriate to include guided training based on dynamic system theory to improve surfer performance. For instance, synergizing, which is the combination or coordination of the activity of (two or more agents) to produce a joint effect greater than the sum of their separate effects (Chapman et al., 2007; Pol et al., 2020; Torrents & Balague, 2006).

Motor control is defined as the process of initiating, directing, and grading purposeful voluntary movement (Knudson & Hoffman, 2018). Similar to Shumway-Cook and Woollacott (2016), motor control is the ability to regulate mechanisms essential to movement. How does it work in a water environment paddling activity? It is important to note that movement is guided by the following systems: somatosensory, visual, and vestibular. First, the starting position has to be determined. The body collects sensory information from the environment and re-evaluates all deviations, as the position athlete’s position on the surfboard in the water is not stable. Next, the appropriate plan must be chosen to meet the goal, such as take-off on the face of the wave or sprint paddling itself. The plan is coordinated within the central neural system and is executed through motor neurons in the brain stem and spinal cord. The final result is then communicated to the muscles in postural and limb synergies. Based on the activity, motor units fire synchronically in a specific manner (Ambler et al., 2011; Paillard et al., 2011). Finally, the organization and production of movement is a complex problem, so the study of motor control has been approached from a wide range of disciplines. Thus, giving rise to new models describing the motor control of human movement (Pol et al., 2020; Vařeka, 2021).

Motor learning is the appearance of a relatively permanent change in performance or behavioural potential achievable through direct experience or observation of others (Roberta et al., 2020). In the same vein, Zhou et al. (2021) defined motor learning as the degree of skilled performance in a wide range of motor tasks, as well as the quality, coordination, and control of movement underlying a particular motor outcome. It is worth mentioning that, in contemporary sport science, researchers aim to establish an explicit strategy of motor learning to enhance performance (Kearney & Judge, 2017). Williams and Hodges (2012) adopt another perspective, claiming that implicit sport skill acquisition has more benefits. Regardless of the bipolarity of the mentioned opinions, a systematic review of van Abswoude et al. (2021) confirms the advantages of both approaches in children. Likewise, Kal et al. (2018) offer a comprehensive review of skill acquisition strategy with slightly superior evidence on implicit motor learning in adults. Despite these facts, one thing is clear, the key factor for motor learning is versatility, which also resonates with dynamic system theory in sport and the rationale of the article called 'Exploring to learn and learning to explore' (Cristina-Elena & Liliana-Elisabeta, 2014; Hacques et al., 2021; Pol et al., 2020). Versatility means that the athlete should have good coordination of the following components: spatial-temporal orientation ability, kinaesthetic differentiation ability, agility, rhythm ability, and balance ability. These components are considered fundamental motor skills and their coordination is essential for sport-specific skills (Cristina-Elena & Liliana-Elisabeta, 2014). In addition, training stereotype leads to performance stagnation as well as diminution of capacity to build neural pathways to utilize the ability of neural system - plasticity (Heidrich & Chiviacowsky, 2015; Roberta et al., 2020). In conclusion, sport coaches should adopt an implicit and explicit strategy of motor learning in their training methodologies and consider the training versatility of their charges (Cristina-Elena & Liliana-Elisabeta, 2014; Kal et al., 2018; Pol et al., 2020; van Abswoude et al., 2021)

2.5.1. Factors affecting surfing performance

Given that current research focuses on the evaluation of sprint paddling performance, it is important to mention aspects that influence human motor behaviour and can directly affect the results of the research. From the available literature related to this topic, the following elements were chosen and described in more detail. Among the main aspects that determine sprint paddling performance are **gender** (Anthony & Brown, 2016; Parsonage et al., 2018;

Parsonage et al., 2016; Silva et al., 2018; Wheaton & Thorpe, 2018), **anthropometry** (Barlow et al., 2014b; Coyne et al., 2016; Fernandez–Gamboa et al., 2017; Sheppard et al., 2012a; Sheppard et al., 2012; Sinclair et al., 2017), **participation level** (Coyne et al., 2016; Coyne et al., 2017; Farley et al., 2013; Furness et al., 2014; Furness et al., 2015; Furness, Hing, et al., 2018; Loveless & Minahan, 2010a; Minahan et al., 2016) and finally the role of **age** (Breuer & Wicker, 2009; Furness et al., 2014; Nathanson et al., 2002; Pickering et al., 2021; Sheppard et al., 2012a).

2.5.1.1. Gender

Despite the effort to defend women's rights in the context of equal conditions in surfing, one issue is obvious. Surfing performance between women and men is not comparable (Anthony & Brown, 2016; Wheaton & Thorpe, 2018). Although males and females are judged separately during competition, recreational females must compete against males for waves in the line-up. The great difference between men and women, which favours men, reduces the opportunity for female participants to achieve so many waves, and in particular waves of higher quality, thus reducing the opportunity for improvement and the joy of sport (Anthony & Brown, 2016; Parsonage et al., 2016). To be more specific, two primary differences are speed and strength and are due to physiological and anatomical differences (Anthony & Brown, 2016). This opinion is consistent with the results obtained by Secomb et al. (2013), as he found gender differences in sprint paddling velocity in competitive surfers. Their experimental setup is probably based on Sheppard et al. (2012), who found a relation between upper-body pulling strength and peak paddling velocity. In conclusion, gender is the main aspect that might influence surf sprint paddling performance (Parsonage et al., 2016; Secomb et al., 2013; Sheppard et al., 2012).

2.5.1.2. Anthropometry

The consideration of surfing anthropometry seems to be a key factor in better understanding the results of surfing performance and may also help in the talent detection process (Sinclair et al., 2017). It has been widely reported in the surfing population for both juniors (Sheppard et al., 2012a; Tran, Lundgren, et al., 2015) and adults (Coyne et al., 2016; Sinclair et al., 2017). Additionally, knowledge of observed anthropometric variables can facilitate the talent identification process (Sinclair et al., 2017). The fundamental variables are height and weight. Although specific variables are meaningful, others must be related to these basic variables (Coyne et al., 2016). A crucial specific parameter seems to be arm span due to the larger area necessary for pushing phase of sprint paddling. This finding was confirmed for the performance of the 5m and 10m sprints (Sheppard et al., 2012) and also in a one physiological study (Furness, Hing, et al., 2018). Coyne et al. (2016) study extend work by Sheppard et al. (2012) as he used relative arm span. Even the result of this work confirms the previous finding. Next, Sinclair et al. (2017) and Coyne et al. (2016) published controversial studies on the measurement of the biacromial width. While Sinclair et al. (2017) have found anthropometric differences between group of paddlers and non-paddlers, Coyne et al. (2016) was aiming to analyse upper body strength as a prerequisite for sprint paddling performance and biacromial width. His results do not suggest superior performance in competitive and recreational surfers. In summary, the characterization of anthropometry is important to understand surfing performance and the talent identification process. To build a reliable knowledge base for specific variables, more comparative studies in the surfing population are needed (Coyne et al., 2016; Sheppard et al., 2012; Sinclair et al., 2017; Tran, Lundgren, et al., 2015).

2.5.1.3. Participation level

Over the past decade, research has focused on the sport-specific demands of surfing to decide on better training strategies. For this reason, the methodologies describe the inclusion of recreational surfers, in addition to competing surfers, to easily identify differences between these surfing cohorts. It is generally expected and acknowledged that differences between groups will vary, with greater evidence for competing surfers (Farley et al., 2013; Furness, Hing, et al., 2018; Loveless & Minahan, 2010a; Minahan et al., 2016). Specifically, previously reported results on a 400m endurance time trial have shown a higher level of evidence for competing surfers tested in the pool. This finding suggests that aerobic training is essential for prolonged surfing enjoyment (Farley et al., 2013). Next, in interpreting the data, Minahan et al. (2016) observe that the main energetic system for sprint paddling in junior athletes is anaerobic. The study proved that key performance variables are peak sprint power and accumulated O_2 deficit and are in line with those of Furness, Hing, et al. (2018), who further extended the methodology by evaluating the aerobic fitness of adult surfers in the laboratory settings. Similarly, another Australian research group of Coyne et al. (2016) examined the aerobic and anaerobic fitness of an adult surfer in a water environment, which adequately represents real conditions. Higher velocities for competitive surfers were recorded in 5m, 10m, 15m sprint paddling, and 400m endurance paddling. Interestingly and wisely, Coyne further used the results of his study to design an exercise program for both surfing cohorts, where he confirms the original hypothesis (Coyne et al., 2017). Regardless of the environment, aerobic and anaerobic energy pathways are an essential parts of surfing training for junior and adult competitive athletes (Coyne et al., 2016; Furness, Hing, et al., 2018; Minahan et al., 2016).

Taking into account epidemiological studies, interesting results could be obtained in surfing counterparts, competitive, and recreational athletes (Furness et al., 2014; Furness et al., 2015; Nathanson et al., 2002). Nathanson et al. (2002) work has made a significant contribution to the field by developing questionnaires and distributing them to surfers in over 48 countries. As noted in the conclusion, more advanced surfers appeared to be at increased risk of injury. Similarly, Furness et al. (2015) advanced in creating a questionnaire for acute and chronic injuries (2014). In his more recent work, he proved that Australian competitive surfers spent more time in the water compared to recreational surfers; unlike the previous study, where there was no difference between the groups. The chronic injury study also revealed a high likelihood of sustaining a chronic injury in surfers who do not complete aerial manoeuvres (propelling in the air and landing back on the face of the wave) manoeuvres and that the injury rate of recreational surfers is higher. According to Sheppard et al. (2013), the main problem may be a poorly developed paddling technique. Considering the study of acute injury, as already mentioned, competitive surfers spent more time in the water. This is probably why they have more major injuries. Furthermore, the independently evaluated group were aerialists who had the highest incidence proportion of injuries, mainly located in the lower extremities. To conclude, due to poor technique and lower involvement in surfing activity, recreational surfers may experience chronic injuries. Unlike recreational surfers, a higher level of self-confidence for competitive surfers allows them to perform acrobatic manoeuvres, such as aerials, and thus create more acute injuries than their counterparts. 'Nothing venture, nothing gained' or the Czech idiom 'Who does not fall down rides below their limits' suggests that risk is essential for competitive surfing, as creativity and difficulty of manoeuvres are judged during surfing tour. For this reason, prevention in competitive surfers should be a crucial aspect for a long and successful career (Furness et al., 2014; Furness et al., 2015; Lowdon et al., 1996; Sheppard et al., 2013).

2.5.1.4. Age

Among other aspects that influence surfing performance and based on which motor behaviour can be described is age (Furness et al., 2014; Nathanson et al., 2002; Sheppard et al., 2012a; Tran, Lundgren, et al., 2015). Papers by Tran, Lundgren, et al. (2015) compared performance between non-selected and selected elite athletes for the Australian National junior team with mean age 16.13 and 16.18 years. The group representing Australia in the World Tour had a consistently better result in 5m, 10m, 15m sprint and endurance paddling. With her methodology, she followed up on colleagues evaluating the differences between junior and adult surfers (Sheppard et al., 2012a). Competitive juniors (domestic competition) in this research showed slower performance in all aspects. The key factor that causes the difference in results may be age (14.13 years) or level of competition. Considering competitive adults, performance varies on behalf of adults, but not surprisingly can be compared to the results of elite juniors. Apart from competition level, Sheppard et al. (2012a) founded an indicator that may decide about the performance. With regard to body weight, the strength was significantly higher in adults because it is undoubtedly certain that the juniors did not complete the physical development. Furthermore, the tested adult group was relatively young (23.9 years) so it is expected that older surfers will be oppositely slower. This assumption supports a 20-year longitudinal study on decreasing sports activity and performance comparison between young and master sprinters (Breuer & Wicker, 2009; Pickering et al., 2021). To our knowledge, there is no evidence of an older group of surfers evaluated in sprint paddling. For this reason, sprinters were chosen, as the energetic pathways seem to be comparable (Borgonovo-Santos, Zacca, et al., 2021). Furthermore, an age-related difference was detected in the occurrence of injuries. Furness et al. (2014) and Nathanson et al. (2002) reported that older surfers were the risk group for injuries. These results may be due to a decrease in sports activity over a lifetime with the weakening of resilience (Breuer & Wicker, 2009). To summarize, age-related differences are indicators of athletes' performance and, in addition, also show fragility toward injury (Furness et al., 2014; Nathanson et al., 2002; Sheppard et al., 2012a; Tran, Lundgren, et al., 2015).

2.6 MOTOR TESTS RELATED TO SPRINT PADDLING PERFORMANCE

Athlete testing has become a necessary procedure to detect and identify gifted talents. Specific tests can also serve as a variable in evaluating the effectiveness of an intervention aimed at increasing the performance of athletes, monitoring personal improvement over the competing season, or designing a specific training plan (Axel et al., 2018; Draper et al., 2021; Sinclair et al., 2017). The utilization of testing batteries has been widely reported in various sports; for example, male and female soccer (Del Basso, 2019; Hughes et al., 2012), soccer, basketball, and rugby (Pino-Ortega et al., 2021), climbing (Draper et al., 2021), but also in surfing (Axel et al., 2018; Klingner et al., 2021; Silva et al., 2018).

2.6.1. Sprint paddling motor tests

There are many motor tests, which can be used for motor testing in sprint paddling performance. In the following part we describe five of them considering the sport-specific demands of surf sprint paddling. On top of that, all tests have normative values for a higher quality of data identification.

2.6.1.1. Seated Medicine Ball Throw Test (SMBT)

SMBT is a test based on which can be obtained data on '*light load upper body pushing power'* (Beckham et al., 2019*)*. First, the light load may be difficult to define. But in our eyes, the light load may be seen as a water resistance overcome during surf paddling. Furthermore, upper body pushing activity predominantly involves elbow extensors. This statement is further corroborated by the electromyographic analysis of sprint paddles by Nessler et al. (2019), proving that one of the main muscles responsible for propulsion during paddling is the triceps brachii. Sheppard et al. (2012) adopted another perspective, claiming that pulling exercises, such as pull-ups, improve paddling performance without further explanation. However, current research agrees with the opinion of Coyne et al. (2017) and Langenberg et al. (2021), who argue that in paddling activity, athletes pull and then push their body over and through the water surface. Furthermore, surfing research has already standardized that the adaptation of elite surfers to the load corresponding to sprint paddling is the development of anaerobic pathways (Klingner et al., 2021). For this reason, it seems rational to choose a test that evaluates power. For the arguments mentioned above, we believe that this test is appropriate and corresponds to the nature of the paddling activity test.

2.6.1.2. One-Leg Stand Test (OLST)

OLST is one of the tests that is part of the ALPHA-FIT test battery for adults. The benefits of the test is field usability and the ability to obtain information about the *'postural control'* of the individual (Becea et al., 2017). As it was previously reported by Mendez-Villanueva and Bishop (2005), that balance is considered important in surfing due to the dynamic water environment in which surfing places high demands on sensorimotor capabilities (Tran, Nimphius, et al., 2015). Paillard et al. (2011) and Chapman et al. (2007) validate the existing theory on the need for postural control during surfing. The experimental design of their studies provides proof that surfing experience indicates a change in postural control strategy when surfers were performing with divided attention and, further, that more experienced surfers could shift the sensorimotor dominance from vision to proprioception for postural maintenance. However, in the discussion of Alcantara et al. (2012), scientists have concluded that the results of their study did not reveal significant differences in static balance within their surfing cohort.

2.6.1.3. Trunk Lift Test (TLT)

TLT Is associated with the FitnessGram testing battery. The test was designed to identify changes in *'back extensor strength and lumbar flexibility'* (Johnson & Nelson, 1986). The suitability of this test may explain Nessler et al. (2017) with electromyographic analysis. The results of this study suggest that the primary muscle involved in paddling activity is the spine erector. Nessler et al. (2017) data confirm Sheppard et al. (2013) and point out the most frequently utilized paddling position with chest-up. Given the high performance in sprint paddling, the authors' findings may lead to the conclusion that the most appropriate technique in terms of maximum speed is a low chest position. Regardless of the technique, insufficient neuromuscular control of the stabilizing muscles of the trunk together with lumbar stiffness has been reported to be involved in low back pain, and therefore, these shortcomings may be at least partially responsible for the discomfort experienced by surfers during paddling (Hanchard et al., 2021b; Nessler et al., 2017). Furthermore, in physical therapy research, Cope et al. (2019) suggest that improved lumbopelvic control is related to improved athletic performance and decreased shoulder injury, which current research considers as the desire of every surfer. In summary, the trunk lift test represents back extensor strength and lumbar flexibility. Thus it may indicate the level of performance of surf athletes or the level of neuromuscular control of the stabilizing muscles of the trunk. The conditioning of these components is relevant for shoulder and lower back injury management (Cope et al., 2019; Hanchard et al., 2021a; Johnson & Nelson, 1986; Nessler et al., 2017).

2.6.1.4. Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST)

CKCUEST is an objective and easy functional test that can be used to measure components of muscle *'performance of the shoulder complex in a closed kinetic chain position and places high demands on its stabilizers'.* Furthermore, the test movement requires *coordination between the muscles of the trunk and the entire arm* (Schilling & Elazzazi, 2021). Its utilization in sports has been reported in baseball, softball (Schilling & Elazzazi, 2021), basketball (Hollstadt et al., 2020), volleyball, tennis, and handball (Borms & Cools, 2018). Unsurprisingly, all the above-mentioned sports are characterized as an overhead activity, and that is, without a doubt, surfing as it was already described within surfing literature (Langenberg et al., 2021). Moreover, a more solid base for deciding on test inclusion established Coyne et al. (2016) by assimilation sprint paddling performance to closed kinetic chain activity, or at the very least a quasi-CKC for which it is essential to stabilize the shoulder in order to perform powerful paddling strokes (Ellenbecker & Aoki, 2020). Regardless of the kinetic chain theory, as described in the electromyographic analysis of Nessler et al. (2019), paddling at different intensities requires specific coordination of the torso and shoulder muscles. This finding goes hand in hand with the description of CKCUEST. Given these points, CKCUEST seems to be an appropriate tool to evaluate coordination of trunk with upper extremities as part of closed kinetic chain activity, which is related to surfing and fits sprint paddling activity profile (Coyne et al., 2016; Nessler et al., 2019; Schilling & Elazzazi, 2021).

2.6.1.5. Sit-Ups Test (SUT)

Lastly, Sit–Ups Test aims to monitor the development of the athlete's *'abdominal strength and power'* (Davis et al., 2000). More elaborate work by Millar et al. (2021) supports this fact with evidence on kinesiology analysis during sit-ups. Based on their online article, the current work accepts the following explanation. The anterolateral abdominal wall muscles act as stabilizers, while the hip flexors are prime movers and pull the torso towards the lower extremities. For this reason, it seems to be evident that a good trunk stabilization system is a prerequisite for higher performance in overhead athletes (Cope et al., 2019). Furthermore, the actual energetic test requirements are in line with the sport-specific demands of sprint paddling (Furness, Hing, et al., 2018). Therefore, for evaluation of prerequisites for sprint paddling performance; sit-ups test could be an additional tool for determining hip flexor explosive strength, which may be important during pop-up (transition to vertical position). To do so, it is essential to push to the board rapidly and flex the extremities to land on both feet and ride the wave (Eurich et al., 2010).

2.6.2. Analysis of surfboard kinematics to identify KPIs

Utilizing kinematics is a way to describe the motion of the points, and thereby obtain information about the position or velocity of the tracking. It includes concepts such as distance or displacement, velocity, and acceleration and looks at how those values vary over time (Rana & Mittal, 2021). In surfing, multiple works that evaluate sport-specific performance using kinematics analysis, for example, evaluation of paddling (Borgonovo-Santos, Zacca, et al., 2021; Coyne et al., 2017), pop-up analysis (Borgonovo-Santos, Telles, et al., 2021), or landing an aerial (Dowse et al., 2021; Lundgren et al., 2016). Current research uses recently developed technology of an inertial measurement unit (IMU) for the collection of data during sprint paddling. As a result of the application of these technological tools, which have experienced accelerated growth and evolution, the researcher can decide on performance variables to identify KPI's (Pino-Ortega et al., 2021). As basic variables that describe surf paddling performance, we can consider similar variables as in swimming, where scientists concluded that the main performance indicators are stroke length, stroke rate, velocity, or acceleration (Mooney et al., 2016). Furthermore, it may be decided on the as very important premise for better paddling performance can be considered level of a postural stability.

2.7 STRENGTH AND CONDITIONING TRAINING IN SURFING

Surfboard riding has experienced a ‘boom’ in the number of participants and media attention over the last decade at both the recreational and competitive levels (Mendez-Villanueva & Bishop, 2005). Despite the growing global audience, contemporary methodologies do not provide a multidisciplinary approach to improve surfing performance (Piggott et al., 2020). On the contrary, the monodisciplinary approach article by Coyne et al. (2017) developed an experimental design to find whether maximal strength training improves sprint and endurance paddling. The authors' findings are consistent with the observations of Tran et al. (2017b) exploring the effect of detraining on strength, power, and sensorimotor ability in adolescent surfers or likewise in Anthony and Brown (2016), who described specifics of resistance training for female surfers. Considering these papers, Donaldson et al. (2021) recently managed to provide a scoping review with the demonstration of paucity and low level of evidence in peer-reviewed literature relating training methods to surfing performance. Based on the knowledge of these studies, the current work was created by combining a multidisciplinary approach, which in this case includes conditioning and physical therapy.

2.7.1. Desirable athletic qualities integral for surfing

Surfing is an activity characterized by intermittent bouts of exercise of varying intensities and durations that involve different body parts and numerous recovery periods. The duration of the surfing session typically ranges from 20 minutes in a competition to more than 4 to 5 hours during good wave conditioning practice sessions. Moreover, surfing training and competition can be performed in a wide range of environmental conditions (e.g., wave size, type of breaker, line-up situation). These variables are likely to have an impact on the underlying physiological demands of surfing practice. To cope with ocean demands, surfers must respond to long periods of intermittent exercise, while extremity involvement varies depending on the activity performed in the water. The upper body tends to be involved during arm paddling, whereas the lower body is active after a successful landing on a surfboard in order to ride a wave (Mendez-Villanueva & Bishop, 2005). These findings demonstrate that to improve surfing performance; in our case sprint paddling, it is recommended to work not only on dynamic balance or upper body aerobic fitness but also on the optimal level of upper body strength and power as an important component for successful performance in sprint paddling (Anthony & Brown, 2016; Barlow et al., 2015; Borgonovo-Santos, Zacca, et al., 2021; Farley et al., 2012; Furness, Hing, et al., 2018).

2.7.2. Physical therapy as a part of the conditioning program

To our knowledge, no one has so far addressed the inclusion of physical therapy and its principles to prepare a surf conditioning program. From the analysis of the available literature on this topic, it can be deduced that research is stagnant and still uses uniformly focused fitness plans (Anthony & Brown, 2016; Donaldson et al., 2021; Everline, 2007). To date, the application of this discipline in sport has been well reported in injury management and prevention (Cope et al., 2019; Joseph et al., 2018), or other sports such as swimming (Karpiński et al., 2020), kayaking (Davidek et al., 2018), and futsal (Jebavy et al., 2020) in order to improve athletic performance. For this reason, we consider it important to include techniques and principles that are commonly used in physical therapy practice. To illustrate, the evidence-based myofascial chain theory explained by the tensegrity model serves to understand the interconnection and transmission of forces between muscle groups (Wilke et al., 2016). Knowledge of this concept may help visualize the mechanical concept of kinetic chains, which was already described in paddling activity (Coyne et al., 2016). Additionally, the respiratory physiotherapy intervention demonstrated a positive outcome in soccer players. The theoretical background of this experiment presents evidence of a diaphragm. It is most often associated with respiration and, as is well known, respiration is associated with both postural control and athletic performance (Bostanci et al., 2020). Furthermore, core stability training, also known as deep muscular stabilization targets, is performed on specific muscles that support the spine. Synchronization of coactivation of this musculature system promotes effective transmission of forces to the extremities; this can result in superior performance in athletes (Davidek et al., 2018; Frank et al., 2013; Kibler et al., 2006). And finally, neuromuscular training and motor control challenge the individual to perform tasks with the increased focus of attention. To better understand the concept, it is necessary to mention that exercises are not focused on results or the best performance but rather on technique, fluency, and smoothness performed consciously (Ageberg et al., 2010). The benefits of neuromuscular training have been demonstrated several times among various sports disciplines (Hopper et al., 2017; Minoonejad et al., 2019; Williams et al., 2021). Force absorption, active joint stabilization, mitigation of muscle imbalances while increasing strength of structural tissues (bones, ligaments, tendons) are among the most commonly investigated assets of this approach (Hopper et al., 2017). In conclusion, surfing conditioning programs have not yet been prepared from a different perspective than the coach position to improve sprint paddling performance. However, current work represents evidence-based benefits of implemented principles within sports backgrounds to establish a standard on the development of conditioning programs for surfers (Bostanci et al., 2020; Davidek et al., 2018; Donaldson et al., 2021; Hopper et al., 2017; Wilke et al., 2016).

2.7.3. Periodization of sport-specific training plan

The periodic training program has been shown to be superior in improving strength and power over a long and short training period (Everline, 2007). Bompa and Haff (2009) draw on an extensive range of sources to explain the periodization of the training. Periodization is considered to be a method by which training is divided into smaller easy-to-manage segments. Following this idea, creating these training segments is necessary to maximize physiological adaptation. Improving performance and reducing the likelihood of injury (Anthony & Brown, 2016). We start with the smallest, the microcycle. The timeframe of this segment is up to 7 days. To improve the technical element or develop biomotor ability in athletes, it is essential to repeat the training stimulus, while various training loads should be alternated throughout the microcycle. The aim of this cycle is to induce anatomical adaptations. Furthermore, mesocycle is a period of 1 to 6 months, dependent on athlete-specific goals and phase of training plan (Bompa & Haff, 2009). Between the specific goal of surf athletes, contests or surfing trips can be included (Everline, 2007). In the case of our study, it is the progression of the load through the mesocycle to find variations in the post-intervention evaluation.

2.7.3.1. Surf research on periodized training

Although the benefits of periodized training cannot be denied, primary sources with a surfing background did not show results that would indicate the appropriateness of including this method in surfing practice (Anthony & Brown, 2016; Everline, 2007). Most likely due to the descriptive design of those papers. However, experimental studies by Tran, Nimphius, et al. (2015), Tran et al. (2017a), Caballes (2015) and Axel et al. (2018) demonstrated superior results in the performance of competitive surfers of both sexes after periodized training. The majority of works aimed to evaluate strength, power, or sensorimotor ability, while Axel et al. (2018) create a training plan to enhance core strength; for this reason, his objectivization tools combine indicators of the lower body and core musculature strength. Until now, no studies have examined the effects of a training intervention on any objective measures of wave-riding ability such as speed, acceleration, or gyroscope data (Donaldson et al., 2021). Therefore, a lack of evaluation in water can be deduced with respect to a specific activity, such as sprint paddling (Minghelli et al., 2019).

2.8 CORE STABILITY - A PREREQUISITE FOR SUPERIOR PERFORMANCE

The online Oxford dictionary describes the core as 'the muscles of the torso, especially the lower back and abdominal area, which assist in maintaining good posture, balance.' At the same time stability refers to 'the state of being stable' (OUP, 2020a, 2020b). Regardless of the quality of the dictionary, we can find a deeper explanation of core stability. However, there is no single universally accepted definition (Kibler et al., 2006). Some of the authors present different anatomical models representing the core, and these often differ depending on the context in which they were developed. Some researchers have described the core as a double-walled cylinder with the diaphragm as the roof, the abdominals as the front, the paraspinals and gluteal muscles as the back, and the pelvic floor and hip musculature as the bottom (Sharrock et al., 2011). Meanwhile, other researchers with a specific interest in sports suggest that the core includes all the musculature between the sternum and knees, specifically focusing on the lower back, hips and abdominals. It has also been suggested that the core should include the muscles of the shoulder and pelvis because they are critical in transferring forces across the body (Fig & Santana, 2005). Not only active tissues are involved in maintaining stability, as the thoracolumbar fascia is also considered important (Fan et al., 2018; Willard et al., 2012).

So far, the meaning of a word and anatomical specification have been discussed, thus the following lines will be devoted to the sporting application of core stability. Activities, performed within surfing challenge complex motor skills, such as postural control, balance, or coordination, for which core muscle activation is essential. Butowicz et al. (2016) described that core stability is dependent upon both muscle capacities - strength and endurance. To effectively use muscle capacity, neuromuscular control is also one of the main aspects of core stability. The same author characterises the ability to accurately orchestrate a synchronized muscular response to internal and external perturbations based on sensory information in order to control the movement of the body (Butowicz et al., 2016; Mendez-Villanueva & Bishop, 2005; Nelson et al., 2012). For this reason, current research follows the idea of core stability training, which should be prepared with regard to developing strength, endurance, and neuromuscular control of core musculature.

Our interest is to explain how these structures contribute to stabilisation of the torso during a sports activity. The core acts as an anatomical base for the movement of distal segments, which can move effectively under stable conditions and the forces acting on the limbs are thus transmitted without loss. As proven in (2006), an increase in the rotator cuff by 24% is related to the stabilization of the scapula, controlled by the rhomboid and trapezius muscles. The transmission of forces is mediated by prime movers, muscles extending beyond large joints (shoulder, hip), which initiate the movement and stabilizing muscles (rotators); both are attached to the core (Kibler et al., 2006; Myers, 2009; Williams et al., 2020). Several conditions must be met before the force can be transmitted. As described from the point of view of the physical therapist in Frank et al. (2013), for a functional core, there is important balanced coactivation between the deep cervical flexors and spinal extensors in the cervical and upper thoracic region, as well as the diaphragm, pelvic floor, all sections of the abdominals and spinal extensors in the lower thoracic and lumbar region. The diaphragm, the main respiratory muscle, the pelvic floor and the transversus abdominis regulate intraabdominal pressure (IAP). IAP is known to influence the mechanics of the spine, as benefits have been shown in wearing a lumbar compression brace or a weight belt which both serve to increase IAP, improve spinal stability, reduce spinal loading and muscle loads required for stability (Driscoll & Blyum, 2019).

2.8.1. Prevention and injury management

From a physiotherapy point of view, improving core stability through exercise is a common feature in musculoskeletal injury prevention programs. The study by Huxel Bliven and Anderson (2013) also demonstrated moderate evidence of core muscle recruitment and injury risk rates. Given these points, current research considers it important to study epidemiological studies, to optimize current conditions and specify prevention programs with respect to evidence-based science (Furness et al., 2015; Hanchard et al., 2021b). For example, among the acute non-contact injuries in surfing, the most commonly found were knees and ankles. They are mostly developed within acrobatic manoeuvres to score the highest points possible. As a result of creating a prevention program or treating the injury to decrease the stress on these body locations, the core stability training program seems to be a convenient solution (Huxel Bliven & Anderson, 2013). Another "loco typico" of acute surfing injuries was reported in the shoulders resulting from paddling. Although this topic has received enough attention, as suggested by the title of a recently published article 'The Surfer's Shoulder', to our knowledge, surfing science lacks evidence to evaluate athletes with a shoulder injury after intervention (Langenberg et al., 2021; McBride & Fisher, 2012). However, in a systematic review by Cope et al. (2019) the authors concluded that increased lumbopelvic control decreased the prevalence of shoulder injuries in overhead athletes. Rosemeyer et al. (2015) research results validate the reasoning lastly mentioned on account of the fact that their experiment demonstrated a reduction in shoulder power production subsequent to core fatigue protocol. Furthermore, considering gradual onset or chronic injuries, the most reported injury site is the spine. Probably due to cervical and lumbar hyperextension during prolonged paddling (Hanchard et al., 2021b). This view is supported by Gandhi et al. (2021), who present applied anatomy during paddling. In his opinion, engaging the core musculature while paddling creates a firm paddling platform, unloading the lower back muscles. Therefore, land-based exercises aimed at improving core strength or endurance among surfers are essential. Not only as a prevention of the possible emergence of surfer myelopathy, but also to decrease the level of pain (Aluko et al., 2013). Given these arguments, core stability training appears to be an effective tool to prevent and manage the most frequent surfing injuries (Aluko et al., 2013; Cope et al., 2019; Furness et al., 2015; Gandhi et al., 2021; Hanchard et al., 2021b; Huxel Bliven & Anderson, 2013).

2.8.2. Sport performance enhancement

Evidence for a higher performance of core stability-based training programs has already been proven. The main objective of the methodologies was to demonstrate a better outcome related to an athletic performance test (Davidek et al., 2018; Stray-Pedersen et al., 2006). For example, soccer players improved one-step maximum velocity kick (Stray-Pedersen et al., 2006), sprint and agility (Doğanay et al., 2020), and better balance skills were observed among judokas (Martins et al., 2019). However, surf paddling is considered to be an overhead activity (Langenberg et al., 2021). Thus our proposal about the effectivity of core stability training is aimed at studies analysing upper extremity performance. Male and female handball players showed a superior result in evaluating throwing velocity (Dahl & Tillaar, 2021; Kuhn et al., 2019; Ozmen et al., 2020), baseball players improved throwing accuracy (Lust et al., 2009), and finally kayakers showed a significant increase in maximum paddling force (Davidek et al., 2018). These findings are underlined by the work of Rosemeyer et al. (2015), who used a core fatigue protocol with demonstrable results leading to a reduction in shoulder strength. Given these points, the core stability training program showed superior performance in various sports mainly in overhead activities. However, it is crucial to focus on the content of each programme, since isolated core stability training are less beneficial than sport-specific programmes (Dahl & Tillaar, 2021; Davidek et al., 2018; Doğanay et al., 2020; Reed et al., 2012; Rosemeyer et al., 2015).

3 AIMS

The main goal of this study is to assess the effect of a core stability training programme on surfing sprint paddling performance.

The results of this study can contribute to comprehensive physical training for surf athletes, focused on neglected aspects combining exercises based on physiotherapeutic principles. However, in terms of interdisciplinary work it can positively affect the performance of essential activities during surfing.

Specific objectives and hypotheses

1. To characterize research participants through anthropometric evaluation and anamnestic questionnaire.

2. To assess the effect of a core stability training programme on surfing velocity during sprint paddling.

H_1: A core stability training programme affects velocity by altering the mean velocity.

3. To assess the effect of a core stability training programme on postural stability during sprint paddling.

H_1: A core stability training programme affects postural stability by altering root mean square.

4. To assess the effect of a core stability training programme on the roll tilt of the surfboard.

H_1: A core stability training programme affects surfboard roll tilt by altering the range of motion.

5. To assess the effect of a core stability training programme on specific tests related to surfing paddling performance.

H_1: A core stability training programme affects the performance of individual specific tests.

6. To assess the relationship between the effect of a core stability training programme and physical activity.

H_1: Higher physical activity affects the effect of a core stability training programme.

7. To compare surfing performance variables between beginners and experienced athletes.

H_1: There is a difference in performance between beginners and experienced surfers.

8. To compare surfing performance variables between men and women.

H_1: There is a difference in performance between men and women athletes.

4 METHODS

This study has an experimental design to decide whether core stability training affects maximal surf sprint paddling velocity and 3D spatial movement of the surfboard. In addition to the functional water environment evaluation, five specific physical tests were selected to characterize the physical abilities of each participant based on the sport-specific demands of sprint paddling. On top of that an online survey was used to identify samples of the study.

4.1 Participants

Fifteen surfers were analysed within the current research. Ten males (age: 29.1 ± 5.9 years, weight: 77.2 ± 8.5 kg, height: 181.2 ± 8.1 cm) and 5 females (age: 28.4 ± 4.6 years, weight: 61.8 ± 3.1 kg, height: 165.6 ± 2.9 cm). The initial group consisted of 21 surfers. To be included in the study, participants had to complete four weeks of intervention with two evaluations, that took place before and after the four-week period. Furthermore, another criterion for participation in the study was good health condition with no injury in the last three months. Six surfers have not met the criterion to be included in the study, as a one participant was unable to finish due to violation of ethical norms, four participants did not complete physical training with the final evaluation, and one participant missed the second evaluation (Figure 1). Group characterization was applied within the online survey to obtain demographic, surf-specific, and injury-related data (Furness et al., 2015; Rodríguez-Rivadulla et al., 2020).

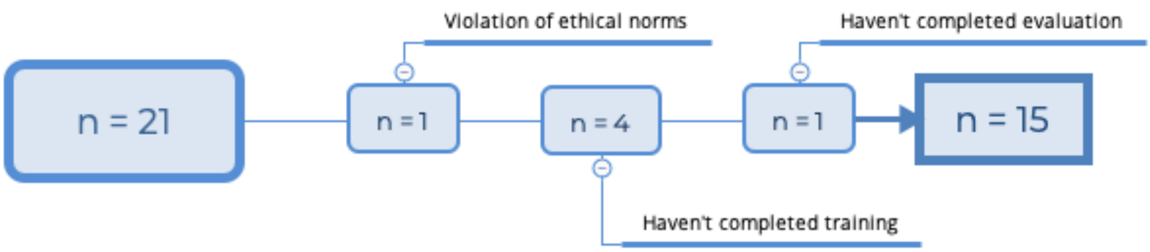

Figure 1. Participation within the study

The research and the informed consent form were approved by the institutional Ethics committee of Palacký University, Faculty of Physical Culture (reference number: 47/2021). A signed written informed consent form was obtained from all participants in this study before the measurements were taken and is attached within the appendix.

4.2 Pilot experimental procedure

An important milestone, the completion of the questionnaire, the evaluation protocol, and the training protocol, made it possible to start the pilot procedure with the first participants. Only a minor change was made in the questionnaire based on the feedback of the first respondent. The incomprehension of the word "dominance" when deciding on limb preferences had to be clarified by a list of examples.

Considering the exercise protocol, the first part of the microcycle was feasible, with minor changes in the next meetings. An impractical method of quantifying a set of static exercises by measured time was changed to a more efficient way of counting. The position (exercise number: 1, 2, 3, 5, 7) should be maintained for 10 breathing cycles when the single one has been designated as exhale and inhale as described in the methodology. Dynamic exercises (exercise: 4, 6) were defined by the number of repetitions but also with respect to respiration. The second part of the microcycle was marked as more challenging but feasible even for recreational surfers. No changes were made to the exercises, except for the repetition specification. The number of repetitions of static exercises (exercises: 1, 4, 6, 8) was controlled by breathing cycles, while dynamic (exercises: 2, 3, 5, 7, 9) was limited by the number of executions of the given positions. During the first cycle, the emphasis was mainly on the breathing technique because most participants were initially confused by the instructions given. Participants should maintain intra-abdominal pressure while activating core muscles; gas exchange was mediated by forced exhalation of the mouth through the open glottis and free inhalation through the nose.

The functional evaluation protocol remained unchanged. On the contrary, the specific evaluation protocol underwent few changes. Pilot testing revealed shortcomings in the protocol and, as reported by participants, difficulties to complete the entire testing protocol. The average reported fatigue time was 3 days, which was detected mainly in the shoulder muscles and the pectorals. We intended to evaluate performance without subsequent physical adaptations, the elimination of MPUT was a crucial step to improve the protocol. Furthermore, another change was applied that improved the determination of the result of the CKCUEST. Firstly, the quantification and decision-making of false touches were originally controlled by more people. For this reason, we had to select a single person responsible for counting all touches, and another researcher identified the error touches and monitored the timer.

4.3 Experimental procedure

4.3.1. Exercise protocol

The surfers underwent four weeks of the core stabilization exercise program. Principally before the training, anthropometric measures such as arm span or biacromial width were also taken. Arm span was measured in standing position facing the wall. The participants then placed their palms on the wall and measured the distance between the most distal parts of the hand, most often the third finger. To acquire shoulder width, the biacromial width was measured in standing positions with arms relaxed parallel to the body (Kopecký et al., 2014). Protocol started with the training repeated twice a week with a minimal interval of two days between each exercise unit. Within the first, the surfers performed isometrical contraction of core stabilisers to maintain the position, while the second contained whole-body movements with an emphasis on precise execution. All subjects were led by a physiotherapist (PT) individually or in a group of 4 people at most. To prevent muscle fatigue throughout the set, it was important for the investigator to observe the decrease in maximal force or power production in response to contractile activity. In this case, subjects were asked to rest before the next repetition (Wan et al., 2017). Repetitions were defined by breathing cycles. In most cases, with intentional inclusion of breathing techniques to improve diaphragm activation by forced expiration (Bostanci et al., 2020). However, the counting of a repetition by changing the position of the segment also occurred. Furthermore, the intervention was divided into several cycles (Figure 2). Initially, the body was expected to adapt to a new stimulus and subsequently increase muscle capacity during the next sessions by applying resistance against movement or strict control of the exercise position (Bompa & Haff, 2009). Finally, due to COVID-19 all participants were

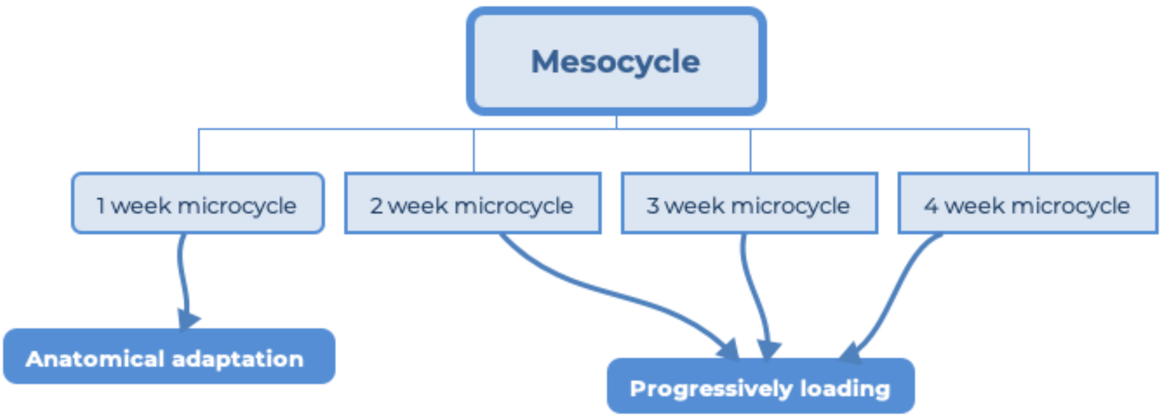

Figure 2. Periodization of intervention

invited to a unique group on MS Teams to continue the experimental phase online (Figure 3). Telerehabilitation effectiveness was proposed in patients with chronic obstruction pulmonary disorder (COPD) or patients with COVID-19 (Bernal Utrera et al., 2021; Michalčíková et al., 2020) current research expects that this reorganization will not affect the results.

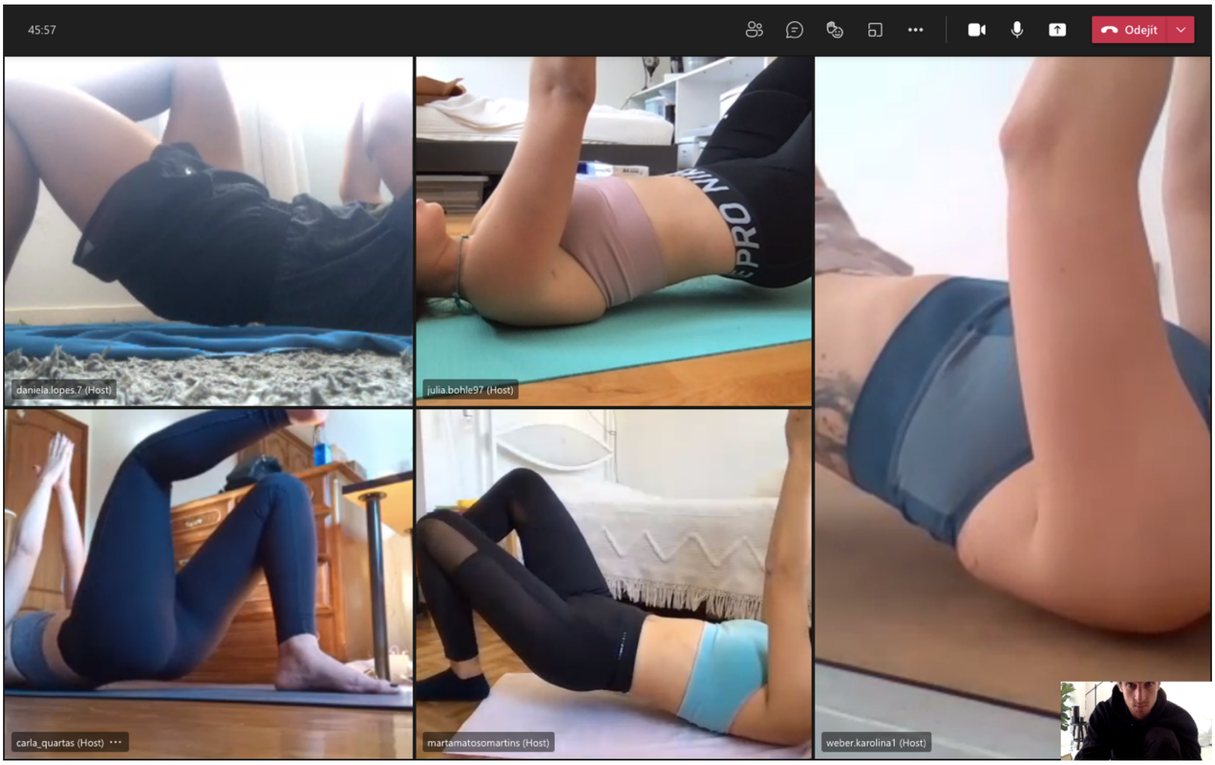

Figure 3. Online class

During the study, all subjects participated in their regular sports routines without restriction. To control the amount of activities, each subject had to fill out the physical activity questionnaire (IPAQ - short form) on a weekly basis. At the end of the study, data were evaluated using Guidelines for Data Processing and Analysis (IPAQ, 2005). The total activity of MET was correlated with the difference between two evaluations (POST – PRE) for each variable of the study.

4.3.1.1. First exercise protocol

The first exercise protocol started with diaphragm activation, followed by various modifications of supinated developmental positions that emphasize links between each body segment connected through muscle chains (Hidetaka, 2020; Wilke et al., 2016).

Table 3. First exercise protocol

NAME OF THE EXERCISE	REPETITIONS	SETS
1. Diaphragmatic breathing	10 x BC | one part of diaphragm	3
2. One–leg supported bridge	10 x BC | each leg	3

3. Leg extension from 3rd month	10 x BC	3
4. Longitudinal rolling	10 x BC | 5 times to each side	3
5. Rhythmic stabilization 3rd month	10 x BC	3
6. Walking pattern in supination	10 x BC | 5 times to each side	3
7. Anterior myofascial activation	10 x BC | each leg	3

1. Diaphragmatic breathing

Initial position: horizontal supine position, knees flexed by 90°, palms placed specifically depending on the part of the diaphragm for which the participant's awareness is focused.

Movement: activation of core muscles, nasal inspiration followed by open glottis exhalation with emphasis on prolonged and targeted activation of expiratory muscles. As soon as the participant inhaled, he was advised to widen the chest in different directions - anterior, lateral, posterior. During the respiratory activity, the deep neck extensors and the shoulder depressor should have been activated and maintained during the set. Ten breathing cycles were performed. for each anatomical part of the diaphragm (Figure 4).

Figure 4. Diaphragmatic breathing

2. One–leg supported bridge

Initial position: supine position, knees flexed by 90°, palms placed specifically on SIAS to control the lateral tilt of the pelvis.

Movement: after the pelvic lift from the exercise mat, the participant slowly transfers the weight to one leg, while the other leg is elevated by approximately 5 cm. Ten breathing cycles were performed while maintaining this position and were followed by changing the legs (Figure 5).

Figure 5. One–leg supported bridge

3. Leg extension from 3rd month

Initial position: supinated position of third developmental month (Gajewska et al., 2018).

Movement: extension of the leg with emphasis on slowness and fluency while exhaling. The movement continues to a position where the individual is unable to maintain a direct position of the spine, and hyperlordosis appears as an undesirable consequence. Subsequently, with a breath, the participants return the limbs to the starting position (Figure 6) (Williams et al., 2021).

Figure 6. Leg extension from 3rd month

4. Longitudinal rolling

Initial position: supinated position of third developmental month (Gajewska et al., 2018). Experienced individuals were recommended to stretch legs up to the border position where they were able to maintain the straightened back.

Movement: rolling along the longitudinal axis has begun from the described position, which should be maintained throughout the set. Subjects were said to roll as far as they could with fixed body positions. In addition, breathing cycles were controlled as it was unified to exhale during lateral movement and breathe in on the way back to the initial position (Figure 7).

Figure 7. Longitudinal rolling

5. Rhythmic stabilization 3rd month

Initial position: supinated position of third developmental month (Gajewska et al., 2018) with arms in front of the chest and clasped hands.

Movement: external load was applied by the executor of intervention in various directions on the upper and lower extremity to simulate the technique of Proprioceptive Neuromuscular Facilitation (PNF) method - rhythmic stabilization (Van Criekinge et al., 2019). As a result of COVID isolation, there was a minor change within this exercise. Subjects were asked to lift the pelvis from the ground without additional synergies of the trunk and head (Figure 8).

Figure 8. Pelvis lift in 3rd month position

6. Supinated walking pattern

Initial position: supinated position of third developmental month (Gajewska et al., 2018).

Movement: the contralateral limbs move simultaneously into extension, while the opposite limbs move into flexion. Granted that a high level of coordination was achieved, participants incorporated breathing synkinesis, expiration together with extension and toward the initial position breath in. Similar attention was paid to the slowness and smoothness of the movement performed, as well as the strengthening of the spine by the core muscles (Figure 9) (Williams et al., 2021).

Figure 9. Supinated walking pattern

7. Anterior myofascial activation

Initial position: supinated body position with triple flexion of the leg and palm placed slightly on the contralateral knee internally.

Movement: pushing against the contralateral knee during expiration with the aim to activate the Front functional line and Spiral line (Wilke et al., 2016). Participants were told to push as much as they could constantly, so that fibre contraction met the criteria to be characterized as isometric (Figure 10) (Hall, 2015).

Figure 10. Anterior myofascial activation

4.3.1.2. Second exercise protocol

The second protocol began identically with breathing activation and progressed to dynamic exercises to improve participant self-awareness, followed by prone development position (Frank et al., 2013; Hidetaka, 2020). Quadruped isometric holds and frontward, backward locomotion were also part of the protocol (Kolář, 2013; Sousa Dantas et al., 2017).

Table 4. Second exercise protocol

NAME OF THE EXERCISE	REPETITIONS	SETS
1. Diaphragmatic breathing	10 x BC | single part of diaphragm	3

2. Oblique side sit reaching with ER	5 x | each side	2
3. Transfer to four–legged support	5 x | each side	2
4. Prone reaching	5 x BC | each arm	2
5. Verticalization step	5 x | each side	2
6. Isometric four–legged holding - LP	10 x BC | each side	2
7. Four– legged locomotion - LP	20 x BC | 10 steps ↑ and 10 steps ↓	2
8. Isometric four–legged holding - HP	10 x BC | each side	2
9. Four– legged locomotion - HP	20 x BC | 10 steps ↑ and 10 steps ↓	2

1. Diaphragmatic breathing

Initial position: horizontal supine position, knees flexed by 90°, palms placed specifically depending on the part of the diaphragm for which the participant's awareness is focused.

Movement: activation of core muscles, nasal inspiration with open glottis followed by exhalation with emphasis on longer time and targeted activation of expiratory muscles. As soon as the participant inhaled, he was advised to widen the chest in different directions - anterior, lateral, posterior. During the respiratory activity, the deep neck extensors and the shoulder depressor should have been activated and maintained during the set. Ten breathing cycles were performed for each anatomical part of the diaphragm (Figure 11).

Figure 11. Diaphragmatic breathing

2. Oblique side sit reaching with external rotation

Initial position: supinated position of the third developmental month (Gajewska et al., 2018).

Movement: slowly rolling to the side along the longitudinal axes, while the arm and elbow on the rotated side are flexed by 90 °. The arm is placed with the dorsal part of the hand touching the ground. Similarly, the contralateral lower limb, which ends in flexion and external rotation. With this setting, it is placed in front of the knee of the other leg. Only if the body is now on its side, vertically to the ground, subjects intentionally activate core muscles. Together with shoulder external rotation and expiration, they lift their trunk as a whole block slowly and smoothly. Meanwhile, the other arm is trying to reach a distant non-existent object in front of the participant (Langenberg et al., 2021; Madeira et al., 2019; Williams et al., 2021). The flexed lower limb is responsible for closing the kinetic chain by active pushing into the pad. As a result of mentioned description subject reaches a modified low oblique sit. From which the subject reverses in the same manner to the initial position. Consequently, with the elevation of the trunk and depression, breathing out ensures the activation of the expiration muscles to support a strengthened spine while breathing in appeared in the highest position of the modified low oblique sit (Figure 12) (Tong et al., 2019).

Figure 12. Oblique side sit reaching with external rotation

3. Transfer to four–legged support

Initial position: supinated position of third developmental month (Gajewska et al., 2018).

Movement: the beginning of the current exercise is identical to the previous one, up to the position of modified low oblique sit (Figure 12). Starting from here, the subject places an extended reaching hand next to the supporting one and simultaneously shifts weight to the flexed lower extremity so that the extended opposite leg can reach the level of supporting one to finish in a quadruped body position. In the same way, but vice versa, the subject continues through the oblique sit position and ends in the initial position. The description of breathing synkinesis is similar to the previous exercise. As soon as exercise includes weight transferring or moving to achieve the required position, participants exhale. Oppositely, once the subject has already reached the static position, modified oblique sit or quadruped position continues with breath in and starts the backwards movement (Figure 13, 14).

Figure 13. Transfer to four–legged support

Figure 14. Transfer from four–legged support

4. Prone reaching

Initial position: pronated position of fifth developmental month (Kolář, 2013).

Movement: three points supported position initiated the exercise: the medial epicondyle of the humerus, the ipsilateral insertion of the quadriceps muscle, and the contralateral medial condyle of the femur. Contraction of the core muscles together with the pelvis lift should ensure that the line interspersed within three joints, shoulder, hip, and knee, is straight. To prevent accentuation of lumbar lordosis, executor should control pelvic tilt. As soon as the desired position is reached, five breathing cycles delimit one set. Moreover, the unsupported arm is trying to reach a distant object and, in addition, the executor might apply external load on this extremity to increase the effort of the subject. The scapula and the humerus depressor are supposed to be activated to connect kinetic chains to keep the shoulder in an advantageous kinesiological position (Figure 15) (Ellenbecker & Aoki, 2020).

Figure 15. Prone reaching

5. Verticalization step

Initial position: quadruped position with knee support, straightened spine (Kolář, 2013).

Movement: during the expiration, the subject abducts, flexes, externally rotates one of the lower limbs to be placed next to the body. The motion should be done independently without any synergy of the muscles within the spine or pelvis, and other monitored factor was the fluency and slowness of the exercise. Once the leg is lifted, participants should not shift body weight on the supporting knee to orchestrate extensive activation of muscles supporting the spine. The breathing pattern is as follows, exhalation on the way to the side supported position, inhalation in statics and exhalation when moving backwards. The contralateral upper limb can also be raised to graduate the load (Figure 16, 17).

Figure 16. Verticalization step

Figure 17. Verticalization step (advanced version)

6. Isometric four–legged holding - LP

Initial position: low quadruped position with foot support.

Movement: after confirming the position, where knees are just above the ground by five centimetres, the subject elevates one foot. It was emphasized to maintain the position of the pelvis during five breathing cycles without any tilt. Once the correct exercise technique was followed, the participants were asked to lift the contralateral upper limb and maintain stability throughout the set as a new stimulus to increase the load (Figure 18, 19) (Kibler et al., 2006).

Figure 18. Isometric four–legged holding - LP

Figure 19. Isometric four–legged holding - LP (advanced version)

7. Four–legged locomotion - LP

Initial position: low quadruped position with foot support.

Movement: from starting position the locomotion continues with simultaneous movement of contralateral extremities forward (Figure 20) by ten steps and then backward (Figure 21). Synchronicity of movement was emphasized to improve coordination by taking steps of equal length and time (Sousa Dantas et al., 2017; Williams et al., 2021).

Figure 20. Forward four–legged locomotion in low position

Figure 21. Backward four–legged locomotion in low position

8. Isometric four–legged holding - HP

Initial position: higher quadruped position with foot support.

Movement: after confirming the position, where knees are almost extended, wrists are below shoulders, and spine is straight, the subject raises one foot. It was emphasized to maintain the position of the pelvis during five breathing cycles without any tilt. Once the correct exercise technique was followed, the participant was asked to lift the contralateral upper limb and maintain stability throughout the set (Figure 22, 23) (Kibler et al., 2006).

Figure 22. Isometric four–legged holding - HP

Figure 23. Isometric four–legged holding - HP (advanced version)

9. Four– legged locomotion - HP

Initial position: higher quadruped position with foot support.

Movement: from the starting position the locomotion continues with simultaneous movement of the contralateral extremities forward (Figure 24) by ten steps and then backward (Figure 25). Synchronicity of movement was emphasized to improve coordination by taking steps of equal length and time (Sousa Dantas et al., 2017; Williams et al., 2021).

Figure 24. Forward four–legged locomotion in high position

Figure 25. Backward four–legged locomotion in high position

4.3.2. Evaluation protocol - functional

The functional evaluation test, surfing sprint paddling, was performed in an aquatic environment in Porto de Leixões to simulate performance in saltwater conditions while avoiding the disturbing effect of open ocean water (Figure 26) (Borgonovo-Santos, Zacca, et al., 2021). Subjects were initially asked to participate in a 5 min warm-up, consisting of 3 min of continuous light intensity paddling followed by three, 5 s total paddling efforts; each 5 s effort was separated by a 30 sec rest period (Figure 28). For this purpose, an experimental surfboard (5’10’’ x 18,75’’ x 2,375’’, 27,46 l) was used with the fluid flow sensor (Riedel Communication, R&D Hub PT, Germany) located on the underside of the board. The participants then rested for at least 5 minutes before being asked to initiate the main evaluation protocol (Figure 27). Subsequently all subjects performed three 20-second tests aiming to achieve the maximum velocity with a 5-minute rest period between each trial. It was not limited to use kicking or just arm paddling, because of different level of surfers (Borgonovo-Santos, Zacca, et al., 2021; Loveless & Minahan, 2010b; Minahan et al., 2016).

Figure 27. Functional evaluation - warm up

Figure 26. Functional evaluation - instruction

Figure 28. Porto de Leixões

4.3.2.1 Treatment of data from the fluid flow sensor

The currently developed sensor was chosen to objectively decide how the intervention affected the sprint paddling performance. After collecting all trials, post- and pre-intervention, the data were cleaned in MS Excel (Microsoft Corporation, WA, USA) using the generated formula and trimmed to obtain an interval of 20 seconds. For this identification, the velocity and Z-axis gyroscope were combined to visualize the beginning of the signal. However, to identify measured variables, we have used an interval of 10 seconds (Borgonovo-Santos, Zacca, et al., 2021). Furthermore, the mean velocity was used to decide about the best PRE and POST trial, which was used for further analysis. In the event of an abnormal curve shape, the attempt was replaced by the second best. Three variables were obtained by dividing the interval into three periods. Reaching optimal velocity (ROV), first four seconds, represents incremental phase, acceleration, respectively. Second interval, six to ten seconds, showing the ability to maintain the optimal velocity (MOV) and lastly overall performance (OAP), full ten seconds (Figure 29). An average was calculated for all measured variables. Next, based on surfboard roll data, we calculated Root Mean Square to evaluate paddling economics and postural stability (Bizovska et al., 2019). The mean roll values were calculated to determine the mean position of the surfboard during sprint paddling. Finally, the peaks in the roll axis were identified using the formula generated in Excel. Subsequent to identification, negative peaks were subtracted from positive ones and range of motion was determined.

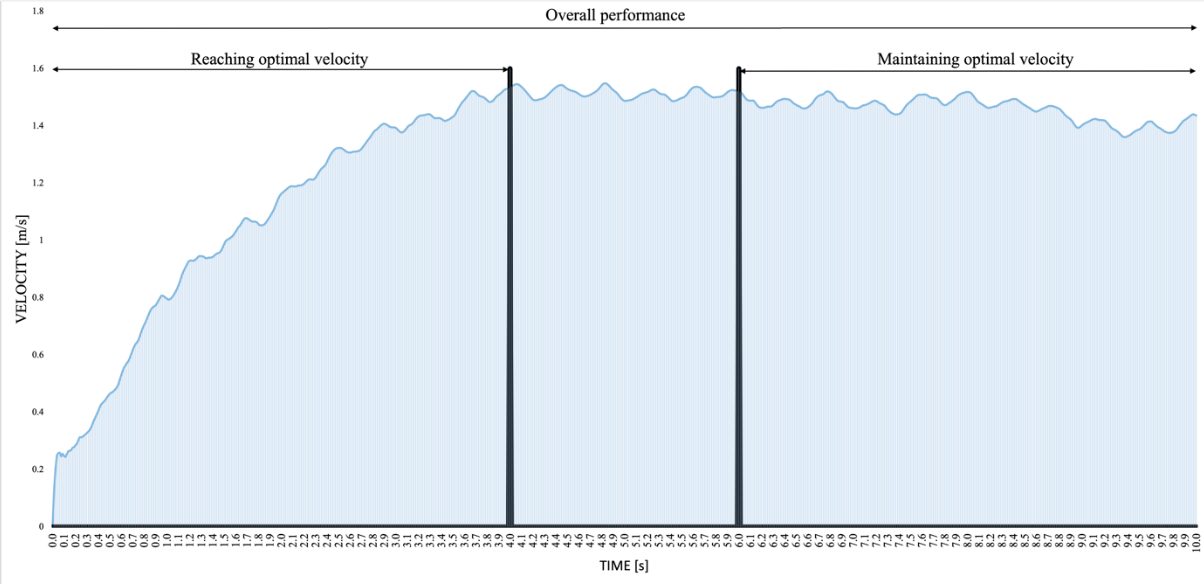

Figure 29. Time intervals within sprint paddling performance

4.3.3. Evaluation protocol-specific

The physical tests, linked to the sprint paddling profile, determined whether core stability training affects performance. Before the test, an individually guided whole-body warm-up was performed for 5 minutes, followed by a testing phase (McGowan et al., 2015). To evaluate light load upper-body pushing power was used, the Seated Medicine Ball Throw (SMBT). Subjects became familiar with SMBT using a 2 kg ball and 5 practice throws (Vrbik et al., 2017). After familiarisation and 2 min rest period, subjects completed 3 test throws with the same technique as familiarisation throw with 1 min interval between each trial. It was important to inform the participants about the starting position that the movement should start with the medicine ball touching their chest while the legs were extended parallel or slightly apart. The posture of the trunk was controlled as the back and posterior part of the head should have remained in touch during the throw. For the correct throwing technique, participants were encouraged to throw the ball at a 45 ° angle but this was neither measured nor restricted. The horizontal distance was measured from the base of the wall to the rearmost point of contact with the ground on landing using a tape measure. The best result of all trials was taken and further compared with normative data (Figure 30) (Beckham et al., 2019; Gaya & Gaya, 2016).

Figure 30. Seated medicine ball throw

Next, to measure postural control with the narrowed support base, One–Leg Stand Test (OLST) was included in the protocol. The test was carried out with subjects standing upright, arms relaxed along the body, and the heel of the unsupported leg placed on the inner side of the knee of the supporting leg, so the thigh is rotated outward. Also, it was recommended to have eyes open during the test and shoes on. Before the measurement was taken, the participants were guided through the trial test to become familiarized with the procedure. The researcher demonstrated the correct execution of the test, and then the participants tried the preparation test to find the preference of the legs. The maximum duration of the test is 60 seconds. The evaluator starts the timing when the subject has reached the correct test position and notices the leg used for the test. Timing stops when the subject loses the balance (i.e. foot of the free leg loses contact from the supporting leg, supporting leg moves) or 60 seconds is reached. Two trials are performed unless the result of the first trial is one minute (Figure 31) (Becea et al., 2017).

Figure 31. One-Leg Stand Test

Another test that measures the short-term endurance and strength capacity of the extensor muscles of the upper extremities and the ability to stabilize the trunk is modified push–up (MPUT). Participants start from prone positions on the mat and begin the push-up cycle by clapping hands behind the back once. A normal straight-leg push-up follows with elbows completely straight in the up position. Then one of the hands is used to touch the back of the other hand before lowering the body again. The subject ends the cycle back in the face-down position with fully flexed arms without the need to contact the mat. If the participant has a limited range of motion in shoulder joints and is unable to clap hands behind the back, the push-up cycle could start by clapping hands to lateral sides of the thighs. Proceeding with the explanation, the research showed the correct test execution. The different phases of the modified push-up are practised once before the measured test. Only one attempt is allowed (Becea et al., 2017).

The fourth test, the Trunk Lift Test (TLT), is part of the FitnessGram testing battery. The test was carried out to identify changes in the strength of the back extensor and lumbar flexibility since most surfers paddle in the chest-up position on the surfboard (Sheppard et al., 2013). Participants were asked to assume a prone position on the ground with their palms in contact with the thighs and parallel to the lower extremities. The researcher placed a mark on the ground at the level of the participant's eyes and prompted him to perform back extension so that the curve of the cervical spine remains unchanged. While the participant performed the slow and controlled movement, the examiner checked if the participant's feet are in contact with the mat. As soon as the highest position is maintained for at least two seconds, the researcher measured the vertical distance between the floor and the participant's chin. The test is repeated three times, and the longest recorded distance is used to assess the athlete's performance (Figure 32) (Johnson & Nelson, 1986).

Figure 32. Trunk Lift Test

Then, to perform Closed Kinetic Chain Upper Extremity Stability Test (CKCUEST), the researcher required two strokes of tape, the fitness mat, and the chronometer. There had to be 91.4 cm between the two strokes of tape. The test was explained and demonstrated by the researchers first. An initial push-up position was assumed with the middle fingers on the tape strokes, feet placed shoulder-width apart, and the arms perpendicular to the hands. In addition, the straight back had to be maintained during the test. For the participant's comfort, the fitness mat was placed underneath the knees. After starting the timer, the subject brought his dominant hand to his non-dominant hand that was supporting at the moment, followed by replacing his dominant hand to the starting

Figure 33. CKCUEST

position. Subsequently, the nondominant hand acted identically. This alternating movement continued for 15 seconds, in which the participant tried to do as many touches as possible. For motivational purposes, the number of touches was counted out loud. Two people were needed to control this test. A researcher counted the number of touches, and another researcher took care of the timing and error touches. For the current study, the following errors were controlled: not touching the hand at all, not touching the dorsal part of the hand, not placing the middle finger on the tape, bending the knees on the ground, failing to maintain feet on the ground, or a straight back. When errors occurred, they were recorded and then subtracted from the counted value. There was a submaximal familiarization test and three performance tests. At the beginning of the performance trials, participants were told to perform the best they could. A rest period of 45 seconds was present between each performance test to avoid fatigue influence. Ultimately, the best score attempt was selected from the three performance tests (Figure 33) (Borms & Cools, 2018; Hollstadt et al., 2020).

Figure 34. Sit–Ups Test

Lastly, Sit–Ups Test (SUT) aims to monitor the development of the athlete's abdominal strength and power. It is required to have a non-slip floor surface, the mat, chronometer, and research assistant to conduct this test. Prior to the evaluation, the test is performed and explained by the researcher. After this procedure, the subject underwent one submaximal tryout. The participant assumed supine positions with the knees flexed 90 ° and the foot flat on the floor, the hands are crossed in front of the chest throughout the test. The research assistant holds the athlete's feet on the ground and gives the command to start the test and stopwatch. During the trial, the athlete sits up, touching the thighs with their forearms, then returns to the floor. Hence the shoulder blades are in contact with the mat, and the athlete continues to perform as many sit-ups as possible in 30 seconds with the motivational support of the researcher. After 30 s of expiration, the number of correctly completed sit-ups is recorded (Figure 34) (Davis et al., 2000).

The identical testing protocol was applied for post interventional measurements.

4.4 Statistical analysis

Descriptive data were obtained for all participants with respect to the group in which they were included. Questionnaire data was rewritten in MS Excel (Microsoft Corporation, WA, USA) and analysed manually. The normal data distribution was confirmed by the Kolmogorov-Smirnov test. Due to the relatively low number of subjects in the evaluated groups, the comparison of the data before and after the intervention was performed using non-parametric tests for all subjects, male, female, beginner, and experienced surfers independently. In addition, the relationship between physical activity and the difference in post-intervention and pre-intervention values was assessed using the Pearson's correlation coefficient. Comparison of groups (males vs. female, beginners vs. experienced) was performed using the Mann Whitney U test. The significance level was set at $p < 0.05$.

5 RESULTS

5.1 Characterization of participants

Based on the questionnaire compiled, participants were divided into multiple groups with respect to the gender (Table 5) and surfing experience (Table 6). For this reason, as beginners were considered surfers, who had previously surfed for a maximum of one year while as experienced who had minimum of two years of surfing experience.

Table 5. Characterization of participants based on gender

	Males (n=10)		**Females (n=5)**	
	Mean	SD	Mean	SD
Age [years]	29.1	5.9	28.4	4.6
Height [cm]	181.2	8.1	165.6	2.9
Weight [kg]	77.2	8.5	61.8	3.1
BMI [kg/m^2]	23.5	2.0	22.6	1.5
Arm span [cm]	184.5	8.6	166.8	5.5
Biacromial width [cm]	44.9	1.7	39.8	1.2
Surf experience [years]	8.8	6.9	2.8	1.6
Surf/week [hours]	4.6	2.5	4.2	2.0
Surfboard volume [l]	34.8	7.9	57	9.8

Table 5 shows a considerable difference between genders in several aspects such as height, weight, arm span, biacromial width, surfing experience, and surfboard volume. However, as can be seen in Table 6, the trend is not similar. The higher level of disparity can be found in age, surf experience, and surfboard volume.

Table 6. Characterization of participants based on surfing experience

	Beginners (n=5)		**Experienced (n=10)**	
	Mean	SD	Mean	SD
Age [years]	26.2	5.5	29.8	5.6
Height [cm]	173	11.6	178.6	10.1
Weight [kg]	71.8	11.5	72.9	10.9
BMI [kg/m^2]	23.9	2.4	22.7	1.7
Arm span [cm]	178.3	12.3	180.4	12.0

Biacromial width [cm]	43.2	3.9	43.3	2.6
Surf experience [years]	0.8	0.5	10.3	6.2
Surfboard vol. [l]	49.8	8.2	34.9	15.1

The next part of the questionnaire collected information about the training habits of surfers, with the finding that most of the surfers do not spend much time warming up or cooling down. Although 93.3 % of surfers reported some time spent on a pre-surfing workout, a similar result for cooling down was not reported, as 66.7 % of participants answered zero or did not answer. However, the average warm-up group time was 8.3 minutes. Among the favourite kinds of warm-up belong static stretching, yoga, functional movements, and, for cool-down, it is stretching, running, or mobility exercises. Furthermore, to receive information about participants motor competencies, they were asked for additional activities they are performing regularly or exercises specially tailored for surfers but performed out of the water with the result that 93.3 % are physically active. Among the most frequently mentioned activities were surf skate, running, football, cycling, and strengthening. The final part of the second section of the questionnaire consisted of questions that examined the participants' awareness of core stability. The majority heard about the core stability concept, but according to further question, exploring the knowledge deeply, not everybody was able to answer how it works convincingly. It was also determined how much time participants spent on core stability training and whether they heard about complementary physiotherapeutic training in surfing. Answers describe that less than half of the athletes have not targeted their training to improve core stability, but a slightly larger half have heard about physiotherapeutic training in surfing.

Considering acute (Table 7, 8) and chronic (Table 9, 10) in surfing, 60 % of the samples have not reported any injury. Those who were injured while surfing are represented by the following tables.

Table 7. Locality and mechanism of acute injuries

Injuries, n = 6 (100%)	Head	Hand	Leg	Knee
Struck by own board	2 (33.4 %)	1 (16.7 %)		
Struck by others board			1 (16.7 %)	
Impact on the wave	1 (16.7 %)			
Manoeuvres				1 (16.7 %)

Table 8. Locality and severity of acute injuries

Injuries, n = 6 (100%)	Head	Hand	Leg	Knee
Major	3 (33.4 %)	1 (16.7 %)		1 (16.7 %)
Minor			1 (16.7 %)	

Table 8 reveals a relationship between the location and the mechanism of acute injuries. The most dominant factor causing the injury appears to be direct contact of the head or hand with the own surfboard. Although contact with other surfboards, impacting the wave or performing manoeuvres is also a risk of injury emergence. It mostly occurs within the head or extremities. Among all the injuries recorded in the current investigation, most of them were major (Table 9).

Table 9. Locality, and mechanism of chronic injuries

Injuries, n = 5 (100%)	Cervical spine	Chest	Lumbar spine
Paddling	1 (20 %)	1 (20 %)	2 (40 %)
Sitting on the board			1 (20 %)

Table 10. Locality, and severity of chronic injuries

Injuries, n = 4 (100%)	Cervical spine	Chest	Lumbar spine
Major		1 (25 %)	
Minor	1 (25 %)		2 (50 %)

Table 9 summarizes the findings of chronic injuries in terms of mechanism and location. The dominant activity for injury emergence was paddling with pain primarily along the spine (lumbar, cervical) and chest. Participants recorded little but significant evidence of prolonged lumbar pain as they sat on the surfboard. The severity of the injuries was mostly minor; however, chest pain made it impossible for one participant to surf for at least one day (Table 10).

The last section of the questionnaire gathered information on the management of surfing injuries, such as the expertise of the healthcare provider, the presence of a physical therapist during treatment, the techniques used to resolve the issue, or participation in the functional rehabilitation training program. Finally, the last question asked about the recurrence of injury after physiotherapy treatment. Only in three cases, there was the presence of a physical therapist. The commonly used techniques in treatment were passive, such as mobilization. However, active exercises were equally applied. Other medical disciplines involved in treating of surfing injuries are surgeons, orthopaedists, otorhinolaryngologists, or back pain specialists.

5.2 Functional testing protocol

5.2.1. Evaluation of velocity

No significant difference was observed between PRE and POST intervention evaluation in following groups males, beginners, experienced. However, female showed a significant difference in ROV (Table 11). Core stability training results in earlier reaching of optimal velocity (mean velocity is higher).

Table 11. ROV values and comparison within the groups

ROV [m/s]		PRE		POST		Difference
Group	n	Mean	SD	Mean	SD	p level
All	15	0.80	0.17	0.82	0.13	0.470
Male	10	0.89	0.13	0.87	0.11	0.374
Female	5	0.63	0.08	0.71	0.11	0.043*
Beginners	5	0.73	0.16	0.73	0.10	0.893
Experienced	10	0.84	0.17	0.86	0.13	0.515

* Significant difference from the first evaluation ($p < 0.05$).

As regards velocity in the period between the 6th and 10th second of the best trial, the analysis did not reveal any significant difference in all groups studied (Table 12). In summary, these results show that core stability training did not affect the ability to perform higher velocity within this interval in surfers.

Table 12. MOV values and comparison within the groups

MOV [m/s]		PRE		POST		Difference
Group	n	Mean	SD	Mean	SD	p level
All	15	1.10	0.21	1.07	0.20	0.925
Male	10	1.21	0.13	1.14	0.15	0.441
Female	5	0.88	0.14	0.93	0.24	0.225
Beginners	5	1.08	0.25	0.96	0.23	0.345
Experienced	10	1.11	0.19	1.13	0.18	0.314

Similarly, no significant effect of core stability exercises on overall performance within sprint paddling was shown (Table 13).

Table 13. OAP values and comparison within the groups

Overall [m/s]		**PRE**		**POST**		**Difference**
Group	n	Mean	SD	Mean	SD	p level
All	15	0.98	0.18	0.97	0.16	0.730
Male	10	1.09	0.11	1.03	0.12	0.086
Female	5	0.78	0.11	0.84	0.17	0.080
Beginners	5	0.93	0.21	0.86	0.16	0.225
Experienced	10	1.01	0.18	1.02	0.15	0.515

Table 14 shows a significant differences between genders. Based on the results, the males had better performance within all measured variables, except MOV and OAP of the evaluation POST intervention. No significant findings were detected among beginners and experienced surfers.

Table 14. Velocity comparison between Males and Females, Beginners and Experienced

Variable	**Measurement**	**Males vs. Females**	**Beginners vs. Experienced**
		p value	p level
ROV [m/s]	PRE	0.003**	0.298
	POST	0.043*	0.098
MOV [m/s]	PRE	0.008**	0.951
	POST	0.098	0.245
OAP [m/s]	**PRE**	0.004**	0.501
	POST	0.058	0.098

* Significant difference between groups ($p < 0.05$). ** Highly significant difference between groups ($p < 0.01$).

Figures 35 and 36 graphically represent the best trial of all participants PRE and POST together with the measured intervals. The better paddlers usually perform higher velocity in all intervals measured. Slower paddlers showed the inconsistency of signal and thus worse performance. Further, it seems that the shapes of the curves fluctuate less than in the first measurement, especially within the MOV interval. This impression further reflects findings in Subchapter 5.2.2. Evaluation of postural stability.

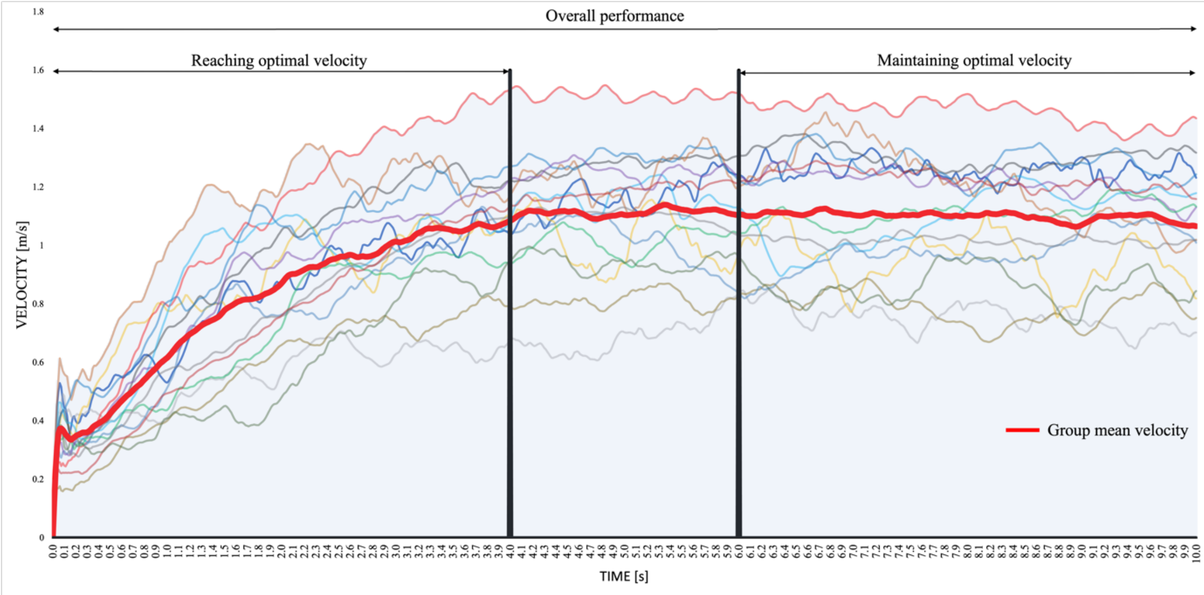

Figure 35. Visualisation of the best trials with highlighted mean value within pre-evaluation of the whole group

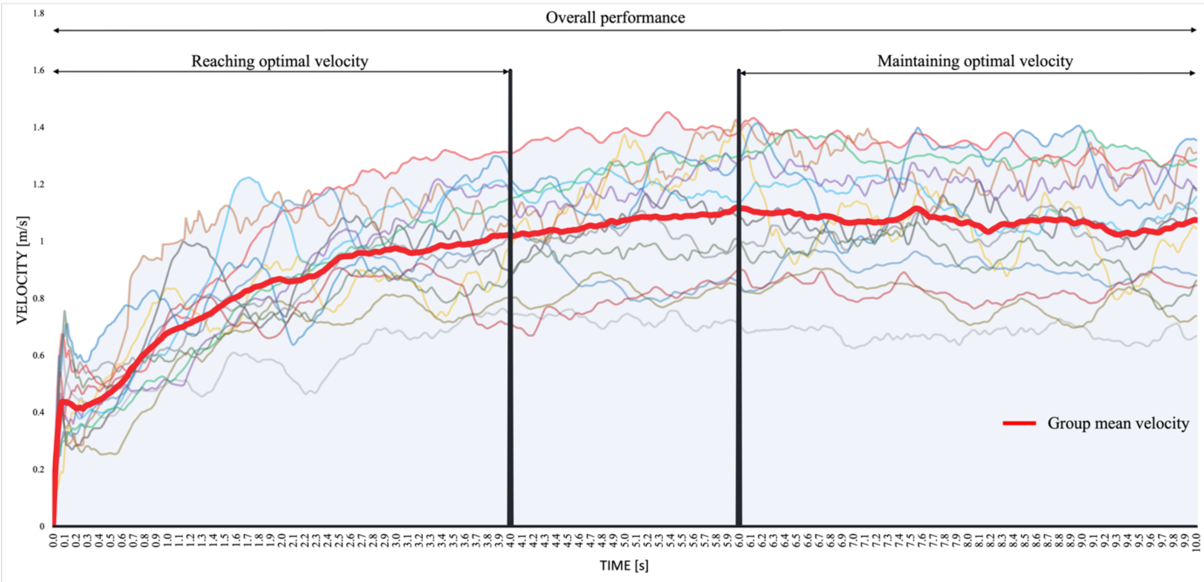

Figure 36. Visualisation of the best trials with highlighted mean value within post-evaluation of the whole group

5.2.2. Evaluation of postural stability

A significant effect of variability training appeared in the performance of the beginners (Table 15). Variability smaller after intervention suggests better stability. Even though RMS was generally reduced in all other groups due to the intervention, none of them improved stability significantly.

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Table 15. RMS values and comparison within the groups

RMS [°]	PRE	POST	Difference

Group	n	Mean	SD	Mean	SD	p level
All	15	6.65	2.17	6.14	1.54	0.112
Male	10	6.97	2.49	6.41	1.69	0.203
Female	5	6.00	1.31	5.60	1.16	0.345
Beginners	5	7.20	0.74	6.39	0.98	0.043*
Experienced	10	6.37	2.61	6.02	1.79	0.646

* Significant difference from the first evaluation ($p < 0.05$).

Although the statistical analysis did not reveal any significant difference as a consequence of core stability training (Table 16). In most groups, it is possible to identify a tendency to roll to one side (Mean). We consider the zero to be ideal for symmetric paddling.

Table 16. Surfboard mean position values within the groups

Position [°]		**PRE**		**POST**		**Difference**
Group	n	Mean	SD	Mean	SD	p level
All	15	-0.84	1.22	-1.14	1.59	0.532
Male	10	-1.14	1.13	-1.54	1.55	0.333
Female	5	-0.25	1.29	-0.33	1.49	0.893
Beginners	5	-0.16	1.32	0.20	1.14	0.138
Experienced	10	-1.18	1.08	-1.81	1.37	0.203

The tendency to decrease ROM values after the intervention is comparable with Table 15 for RMS (Figure 37). Also, for this variable, we have not found any statistically significant difference (Table 17).

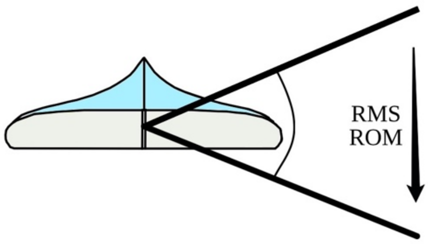

Figure 37. Transversal cut through surfboard to display roll tilt and our findings

Table 17. Peak range of movement values within the groups

ROM [°]		**PRE**		**POST**		**Difference**
Group	n	Mean	SD	Mean	SD	p level
All	15	21.2	6.9	20.1	5.1	0.173
Male	10	22.6	7.9	21.1	5.8	0.241
Female	5	18.5	3.8	18.0	3.0	0.686
Beginners	5	21.7	2.9	20.6	3.6	0.138
Experienced	10	21.0	8.4	19.8	5.9	0.445

If we take into account, the differences between postural stability, gender, and experience do not matter in our case. However, the difference between beginners and experienced surfers within a single variable was statistically significant. The surfboard tilt was higher in POST evaluation in experienced surfers (Table 18).

Table 18. Postural stability comparison between Males and Females, Beginners and Experienced

Variable	Measurement	Males vs. Females	Beginners vs. Experienced
		p level	p level
RMS [°]	PRE	0.501	0.058
	POST	0.426	0.358
Position [°]	PRE	0.159	0.198
	POST	0.298	0.017*
ROM [°]	PRE	0.126	0.245
	POST	0.426	0.582

* Significant difference between groups ($p < 0.05$).

5.3 Specific testing protocol

Although the mean values are higher for each group present, the statistical analysis did reveal no significant difference between PRE and POST values for SMBT (Table 19).

Table 19. SMBT values within the groups

SMBT [cm]		PRE		POST		Difference
Group	n	Mean	SD	Mean	SD	p level
All	15	568	148	592	132	0.112
Male	10	660.2	68.3	670.7	70.5	0.476
Female	5	382.2	29.1	433.6	41.5	0.138
Beginners	5	549.6	165.0	601	156	0.079
Experienced	10	576.5	148.0	587	128.1	0.541

The results of the One-leg Stand Test show no evidence of improved performance in any of the groups examined. All participants achieved the highest possible score in both evaluations. Thus, the absence of significant difference in results can be explained somewhat by inappropriately chosen evaluation tool.

Performance in TLT appeared to be affected by intervention in the group of females (Table 20). However, despite the overall higher values of the other groups, the statistics did not show a significant difference.

Table 20. TLT values within the groups

TLT [cm]		**PRE**		**POST**		**Difference**
Group	n	Mean	SD	Mean	SD	p level
All	15	27.7	6.4	30.3	8.2	0.268
Male	10	28.4	7.3	30.2	9.2	0.575
Female	5	26.4	2.7	30.4	4.5	0.043*
Beginners	5	32.4	9.2	39.2	6.8	0.080
Experienced	10	25.4	2.9	25.9	4.2	0.799

* Significant difference from the first evaluation ($p < 0.05$).

The intervention significantly affected results of CKCUEST in all groups studied. The Wilcoxon test revealed a significant difference between the PRE and POST evaluation at a significance level of $p < 0.01$ in men and experienced surfers. Whereas in group of females and beginners we have found significant difference at a significance level of $p < 0.05$ (Table 21).

Table 21. CKCUEST values within the groups

CKCUEST [reps]		**PRE**		**POST**		**Difference**
Group	n	Mean	SD	Mean	SD	p level
All	15	26.1	3.5	30.7	4.7	<0.001**
Male	10	27.7	2.7	32.7	4.0	0.005**
Female	5	22.8	2.0	26.8	2.3	0.043*
Beginners	5	26.4	4.9	30.8	6.1	0.043*
Experienced	10	25.9	3.0	30.7	4.2	0.005**

*Significant difference from the first evaluation ($p < 0.05$). ** Significant difference from the first evaluation ($p < 0.01$).

In SUT significant difference was found in males, however the rest tested groups remained no significant effect of intervention (Table 22).

Table 22. SUT values within the groups

SUT [reps]		**PRE**		**POST**		**Difference**
Group	n	Mean	SD	Mean	SD	p value
All	15	23.9	2.3	25.7	4.3	0.074
Male	10	24.4	2.3	27.2	4.2	0.033*

Female	5	23.0	1.4	22.6	1.6	0.686
Beginners	5	23.6	2.4	26.2	5.6	0.144
Experienced	10	24.1	2.3	25.4	3.9	0.262

* Significant difference from the first evaluation ($p < 0.05$).

Table 23 shows a several significant differences between genders and surfers of various levels. Based on the statistical Mann-Whitney U test, we can summarize that SMBT and CKCUEST are gender-related physical tests. Also, a significant finding can be seen in beginners, who had a better result in TLT. Other than that, we have not identified any significant results.

Table 23. Specific tests comparison between Males and Females, Beginners and Experienced

Variable	Measurement	Males vs. Females	Beginners vs. Experienced
		p level	p level
SMBT [cm]	PRE	0.003**	0.806
	POST	0.003**	0.759
TLT [cm]	PRE	0.902	0.156
	POST	0.462	0.004**
CKCUEST [reps]	PRE	0.007**	0.537
	POST	0.014*	1.000
SUT [reps]	PRE	0.321	0.710
	POST	0.094	0.852

* Significant difference between groups ($p < 0.05$). ** Highly significant difference between groups ($p < 0.01$).

5.4 IPAQ results

In general, our results showed that physical activity did not affect the results of the variables examined (Table 24). Only one significant correlation was found in MOV.

Table 24. Significance relationship between physical activity and all measured variables

Variable	TOTALMET/min/month	
	Pearson's r	p level
ROV_Dif [m/s]	0.006	0.982
MOV_Dif [m/s]	0.539	0.038*
Overall_Dif [m/s]	0.421	0.119

RMS_Dif [°]	0.164	0.558
Position_Dif [°]	0.139	0.622
ROM_Dif [°]	0.202	0.471
SMBT_Dif [cm]	0.133	0.638
TLT_Dif [cm]	0.494	0.061
CKCUEST_Dif [reps]	0.358	0.190
SUT_Dif [reps]	0.502	0.057

* Significant correlation of evaluation difference and physical activity ($p < 0.05$).

6 DISCUSSIONS

Firstly, it has to be mentioned that, as a whole, the research is, to some extent, a pilot project in several ways. The developed sensor collects kinematic data, which variables can be determined, and the effect of exercise programs can be decided. At present, this type of evaluation does not have international equivalents. Especially when it comes to substantiating the effect of conditioning program on surfing performance in an aquatic environment (Donaldson et al., 2021). Research in surfing has been increasing around databases last years (Borgonovo dos Santos, 2018), while minimum studies discuss the problem of core stability in surfing (Axel et al., 2018). However, there is already verifiable evidence that scientists around the world are targeting their effort to find out what technique (Sheppard et al., 2013) or training (Coyne et al., 2017; Farley, Secomb, et al., 2016; Tran, Nimphius, et al., 2015) improve the most crucial activity, paddling. For this reason, we have prepared a series of motor tests based on sport-specific demands of sprint paddling and a physiotherapy-oriented exercise programme to discover whether the intervention could affect performance. Likewise, we were curious whether core stability training had an impact on surfboard kinematics. Furthermore, as expected, surfing debut at the Summer Olympics in Japan might create a better background for scientists aiming to analyse surfing performance to improve training habits using a multidisciplinary approach (IOC, 2017).

6.1 Anthropometric variables, surfing experience

If we focus on the effect of some anthropometric variables on surf paddling performance, we could consider the difference between genders. Physiological and anatomical differences can explain the key aspects affecting speed and strength (Anthony & Brown, 2016). In the subjects of the current study, descriptive statistics revealed differences in height (181.2 ± 8.1 cm [males] vs. 165.5 ± 2.9 cm [females]) and weight (77.2 ± 8.5 kg [males] vs. 61.8 ± 3.1 kg[females]). Also BMI, which was slightly higher in males compared to females (23.5 ± 2.0 kg/m2 [males] vs. 22.6 ± 1.5 kg/m2 [females]). However, a higher BMI does not take into account the tissue difference. For this reason, we suggest that a higher BMI may be a reflection of lean body mass. Similar results were obtained in the study of Furness et al. (2015) (25.0 ± 3.8 kg/m2 [males] vs. 21.9 ± 2.4 kg/m2 [females]). Furthermore, the arm span differs between the genders (184.5 ± 8.6 cm [males] vs 166.8 ± 5.5 cm [females]). Previous research has proved that a larger area submerged in the water gives an advantage in paddling activity in adult surfers (Coyne et al., 2016; Furness, Hing, et al., 2018; Sheppard et al., 2012). The last two published studies used the ape index, which considers the subject's height. However, in current research, we have used only the value corresponding to the arm span. Another anthropometrical variable that differs between genders is the biacromial width (44.9 ± 1.7 cm [males] vs. 39.8 ± 1.2 cm [females]). Significant differences have also been observed in the study by Sinclair et al. (2017), comparing paddlers with non–paddlers (41.4 ± 1.9 cm vs. 38.8 ± 2.7 cm). We assumed that a narrower arm position disadvantaged athletes because the width of the surfboard may not allow them to immerse their arms deeper, which is a prerequisite for effective paddling. Surprisingly, Coyne et al. (2016) results presented the conclusion that biacromial width is not an important factor in surfers characterisation. There was no relationship between upper body strength, another prerequisite for faster paddling (Coyne et al., 2017), and biacromial width in his study. However, we believe that surfboard width can affect paddling performance.

Next, surfing experience (8.8 ± 6.9 years [males] vs. 2.8 ± 1.6 years [females]) can also be a significant factor influencing sprint paddling, possibly explained by complex system theory. The more time a system (person) spends in a particular environment, the better its performance (Pol et al., 2020). Finally, the volume of the surfboard (34.8 ± 7.9 l [males] vs. 57 ± 9.8 l [females]) was chosen as a factor that could affect paddling performance. It is believed that experienced surfers usually use low-volume surfboards, which represents our results. Logically, an less experienced group of females (2.8 ± 1.6 years) are using surfboards of higher volumes, as paddling those surfboards is physiologically more advantageous (Ekmecic et al., 2017). In the functional paddling evaluation, all surfers used a single surfboard with 27 litres. This condition could be a disadvantage for all surfers who did not have the opportunity to paddle on small-volume surfboards.

Current surfing science compares athletes of different levels to identify differences between competitive and recreational surfers. So far, published articles aim at proprioception and landing skills (Dowse et al., 2020), physiological profile (Farley et al., 2013; Furness, Hing, et al., 2018; Minahan et al., 2016), acute and chronic surfing injuries (Furness et al., 2014), and finally effect of the intervention Coyne et al. (2017). For this reason, we have decided to characterise our samples based on this criterion. Unfortunately, the answers from the questionnaire showed that none of the research participants could not be called competitive. Hence, we have decided to divide them by years of surfing. The highest level of disparity between beginners and experienced surfers in our study can be found in age (26.2 ± 5.5 years [beginners] vs 29.8 ± 5.6 years [experienced]), surf experience (0.8 ± 0.5 years [beginners] vs 10.3 ± 6.2 years [experienced]), and surfboard volume (49.8 ± 8.2 l [beginners] vs 34.9 ± 15.1 years [experienced]). It is assumed that those differences will favour the performance of experienced surfers. Motor learning and dynamic system theory can justify this assumption. However, to our knowledge, it is still not clear which cohort will be more affected by the training programme. The study by Coyne et al. (2017) exploring the effect of strength training on sprint and endurance paddling revealed interesting findings. Firstly, they divided the group based on a criterion ensuring an even distribution, but it was important to compare weaker and stronger athletes to distinguish the effect. As expected, weaker or less experienced athletes are much more likely to accumulate fat-free mass in the initial stages of maximal strength training as it is a novel stimulus. To our knowledge, specific training on core stabilisation is an often-overlooked topic in surfing. For this reason, we believe, it can affect athletes regardless of experience.

6.2 Surfing injuries

A substantial part of the questionnaire consisted of questions about injuries. Intentional interest in questions about training habits leads us to conclusion that most of the surfers do not devote much time for warm-up and almost no time for cooldown. As expected, appropriate warm-up intensity brings various benefits (McGowan et al., 2015). Likewise, it is believed in benefits of active cool-down. Despite this belief, the narrative review by Van Hooren and Peake (2018) does not give any special importance to practice cool-down after activity. Furthermore, it was already reported that the physical preparation of competitive surfers is four times less than in other Olympic sports (Donaldson et al., 2021). Nevertheless, it is important to note that our research did not include competitive athletes. It does not change the fact that physical preparation of surf athletes is insufficient, and we see an opportunity for specialists to improve surfers' performance or to help them stay injury-less. Returning to the answers of the questionnaires, in parallel to surfing, our samples attended other sports activities, which can be beneficial in preventing unilateral loading of the musculoskeletal system. We have registered an increasing interest in surf skating. Off-water activity similar to movement on the surfboard in the water seems to be appropriate tool to practice when ocean is swell less. Performing identical movements in different environments enhances motor learning through neuroplasticity (Roberta et al., 2020). Apart of surf skating, samples participate in common team sports.

Despite the fact that we characterized and divided the samples into different cohorts, for the purpose of injuries, we will discuss them regardless of gender or experience. Of the total number of 15 people, we recorded 6 acute and 5 chronic injuries. Given our results, the critical mechanism of acute or traumatic injuries is contact with the surfboard itself, mostly to the head. These results are in line with those obtained by Furness et al. (2015), Furness et al. (2021) and McArthur et al. (2020), a systematic review. The waves are sometimes hard to predict, and for this reason, one experiencing a wipe-out can easily be hit by his own surfboard. To minimize the risk of injury, surfers should be reinforced to use personal protective gear, and less experienced surfers should be advised to start with softboards. Nathanson (2020) considers wipe-out a skill. For this reason, simulation of wipe-outs in control environment should have been main task for all who may possibly affect learning of beginner surfers. Another critical mechanism is direct contact with other surfboards. In our opinion, most of these injuries occur unnecessarily by disrespecting unwritten rules of surfing ethics. In good conditions, when the peaks are crowded, crossing, entering the wave without priority is common, and thus increasing the risk of injury. Next, among the manoeuvres, we included all activities performed during wave riding. One subject stated to injure his knee during manoeuvres. Similarly, in Furness et al. (2015), where the most dangerous mechanisms were pop-up, tube riding, or aerial. The pattern found here corresponds to the biomechanical study of Borgonovo-Santos, Telles, et al. (2021). Athletes generally shift their weight forward so that the front limb carries a higher load than the rear foot. Finally, most of the injuries were major. The severity indicates whether it was necessary to visit medical care and/or the person had to stay without surfing and/or working for at least one day. Given these points, it is worth considering whether surfers have received adequate help to minimize days without surfing or work. This should be of major interest for companies, as they are paying annually for the medical costs of their employees. Special wellness programs exist and already proved its efficiency (Rezai et al., 2020).

With regards to chronic injuries, there is no doubt that paddling is the most critical mechanism of injury. Minghelli et al. (2019) reported that surfers spend 50.9% of their total time paddling. The collected data are consistent with Furness et al. (2014), Remnant et al. (2020), and Hanchard et al. (2021b), a systematic review. The locality of injuries is characteristic for all the studies mentioned and reflects the description of the paddling anatomy applied (Gandhi et al., 2021). Chronic pain occurs as a result of neck hyperextension and prolonged lumbar extension. Chest injuries are most often associated with prolonged paddling or lying on the surfboard. The skin rubs between the hard surface of the surfboard and the ribs, which can cause painful inflammation. To avoid these problems, it is worthwhile to think about the ergonomics of paddling and the recommendation of core stability training. Reduction of shortened neck extensors and activation of deep neck flexors can be useful for the elimination of neck pain. To minimize lumbar pain, the stability of the core creates a solid platform for paddling, relieves lower back muscles, and can shrink prominent ribs. Although we did not observe shoulders injury in our investigation, we consider it important to discuss this topic. By Furness et al. (2014) it is the second most injured locality; however, by Remnant et al. (2020) even the first. Insufficient capacity of the core muscles affects the strength of the shoulders, and therefore reduced stabilization of the scapula may occur (Rosemeyer et al., 2015). During paddling, the shoulder enters the protraction, which during the pull phase can cause stress on the soft tissues, leading to an increased risk of shoulder impingement. For this reason, we consider it important to work not only on core strength, but also on endurance. Lastly, the severity of most chronic injuries in our study were minor; however, study by Furness et al. (2014) claims the opposite (185 [minor] vs. 883 [major]). Following the same logic as in acute injuries, data can guide sport scientists in preparing specific programs to minimize the occurrence of the most common surfing injuries.

6.3 Evaluation of sprint paddling performance

To the knowledge of Donaldson et al. (2021) there have been no studies that have examined the effects of a training intervention on any objective measures of wave-riding ability such as speed or acceleration. On the basis of our information, the paucity can be confirmed. This study also appears to be the first in which sprint paddling performance was performed for the first time in salty water. This may affect the results, as the buoyant force is greater in comparison with normal water (Nessler et al., 2019). Researchers who had previously examined sprint paddling performance used various tools to collect data. The commonly used is the horizontal positional transducer, attached to the waist or collar of the wetsuit, which enabled to analyse surfers in their natural environment - in the water (Secomb et al., 2013; Secomb et al., 2015a; Sheppard et al., 2012). However, the swimming ergometer has also found its supporters (Loveless & Minahan, 2010b). We believe that the evaluation of athletes in an oceanic environment is the right direction that science should go in. Next, our evaluation protocol is based on the papers of Borgonovo-Santos, Zacca, et al. (2021) and Nessler et al. (2019), who suggested 10 seconds as an optimal temporal frame for sprint paddling evaluation. Additionally, we have split the interval into three sections indicating the performance level. The core stability exercise programme improved ROV in females; for this reason, we think that stabilization exercises played a role when the subject was accelerating to reach optimal velocity. A possible mechanism for this increase could be improving lumbar flexibility and / or back extensor strength and / or upper limb coordination together with better trunk stabilization. The reason for this decision is the significant improvement of females in TLT and CKCUEST. Other variables for velocity were not significant. Our findings also showed gender differences; males had superior performance in majority measurements. The results reinforce the conclusion of Secomb et al. (2013), who compared competitive athletes. Maximum velocity was measured for male (1.77 ± 0.13 m/s) and females (1.55 ± 0.12 m/s). The most probable mechanism for this difference is body composition, anthropometrical and physiological variations such as arm span, anaerobic capacity (Coyne et al., 2016; Furness, Hing, et al., 2018). No differences between beginners and experienced surfers were detected, most probably due to the character of our samples. The entire group was made up of recreational surfers (Coyne et al., 2017). Lastly, on the basis of IPAQ results, we noticed possible influence of physical activity on velocity performance, however, difference in most of the variables within different groups were not significantly related to physical activity. For this reason, we do not consider effect of physical activity as important factor influencing surf paddling performance.

Postural stability appeared to be an important discriminant of experience level in surfers. Competitive surfers showed the ability to shift sensorimotor dominance from vision to proprioception for postural maintenance in laboratory settings (Paillard et al., 2011). To our knowledge, there is no study that evaluates postural control in an aquatic environment. Open ocean water is a dynamically changing environment, and thus, for optimal paddling performance, surfers require a certain amount of stabilization to respond to proprioceptors demands. The logical explanation of our idea is to reduce the drag forces applied to the surfboard as a consequence of core stability training. The variable we focused on was the degree movement around the roll axis. Interestingly, there is only one study in which the authors used inertial measurement units and came up with the following conclusion (Nessler et al., 2019). As the speed gradually increases, the range of motion grows linearly. On the basis of their finding, theory was made concerning the depth of immersed arms. Surfer's roll range of motion increased as they needed to immerse their arm deeper into the water. As a consequence, they ensured a larger area for an efficient push phase within the stroke cycle. However, we believe that this information can be misleading for the interpretation of the findings of our study. Rather than sprint paddling, they evaluated endurance paddling and thus this positive linearity could be compensation of not sufficient core stability, fatigue, respectively. As our interest was to analyse the effect of core stability exercises on sprint paddling performance, the variable used for the identification of postural control was RMS. Frequently utilized in runners (Lindsay et al., 2014), athletes (Blaise Williams III et al., 2016) and soccer players (Thompson et al., 2017). The postural control, variable RMS, improved in the group of beginners; a possible mechanism could be explained by improved stabilization of the trunk muscles and/or better coordination of the upper extremities, because performance also improved in CKCUEST within the same group. Seeing the results closely, we can determine the decreasing pattern of RMS between two evaluations; however, the improvement is not statistically significant. Further, we can conclude that experienced surfers had lower RMS values than beginners. Higher surfing experience may help them predict the surfboard behaviour or keep body more stable. The next variable, the position of the surfboard, represents the mean of the roll values over a period of 10 seconds. Under optimal conditions, the number should be close to zero. Any deviation will cause unwanted drag forces, which affect sprint performance. We hypothesized that this value may also help reveal muscle asymmetries. With the expectation that a significant deviation to one side corresponds to the preference of the arm and thus higher demands on the resistance of soft tissues, mainly in the shoulder area (Hanchard et al., 2021b). Future research should consider this idea. However, since this information has just been created, it is hard to decide which deviation is critical and what is assumed to be a normal value. The results of our samples have not revealed special findings or improvements caused by the intervention, except for comparison between levels. Experienced surfers showed a higher deviation from zero than beginners. For this outcome, we do not have an adequate explanation, as we assume this value to be normal. The last variable to mention is the range of motion between single peaks. Likewise, we expect that the lower number refers to the better stabilization which should correspond to reduced drag forces. The values for each group fluctuate around 20° and no significant findings were observed between the groups or in the evaluation despite a slight decrease in each group. Therefore, it is worthwhile to compare it with the study of Nessler et al. (2019), who reported 26.9° to 44.9°. These numbers only confirm our previous assumption about the importance of stabilization during sprint paddling performance. Lastly, as we have noticed no difference of postural stability among gender, we conclude, that this prerequisite is trainable. A higher level of dynamic balance may help women reduce drag forces and thus eliminate genetic disadvantage, lower strength, or anaerobic capacity (Caballes, 2015).

6.4 Specific tests

The first test, SMBT, is generally a low-risk, accessible, and affordable tool. The test has been already validated in older adults, children, college students, amateur rugby players (Beckham et al., 2019) and is widely used to characterize performance, identify sport talents, or prevent injuries in academic soccer players (Gee et al., 2021), dancers (Coogan et al., 2021) or water polo players (Keiner et al., 2020). The last-mentioned article analysed sport, which seems to be related to surfing. The aquatic locomotion of water polo players is mediated by the use of crawl strokes similar to sprint paddling. Junior players scored 4.97 ± 1.04 m, unfortunately the authors used in methodology a ball weighting three kilograms. Being aware of this difference, the initial results of most of the research groups, except women, were better (660.2 ± 68.3 [males], 549.6 ± 165.0 [beginners] 576.5 ± 148.0 [experienced]). Considering the exercise programme, the majority of exercises challenged strength, endurance, and neuromotor control, so the absence of power-oriented exercises could affect the results. Despite the fact that the performance increased in all groups, the results were not statistically significant. Lastly, when focusing on the comparison between genders, men showed superior performance than women. As in general, men usually perform this test better due to a higher level of strength. This finding reflects the velocity performance within the functional evaluation protocol.

A downside of the methodology used is choosing the One-Leg Stand test to evaluate static balance. The normative tables of the ALPHA–FIT Battery for the OLST test show that a high level of fitness was achieved by 80 % males and 83% females ranging age 30-39. In our case, all surfers completed the test with the best result. This may suggest that the surfing cohort has a better static balance than the normal population. However, due to the dynamically changing environment during surfing session, a reasonable choice would be a tool evaluating dynamic balance (Alcantara et al., 2012). For this reason, we suggest the elimination of this test from our specific sprint paddling test protocol. At the same time, we propose a suitable and affordable alternative to use, the Y-balance test (Benis et al., 2016; Freeman et al., 2013).

Within the reliable Trunk Lift Test, it is impossible to say with certainty whether we evaluate strength and power of back extensors or flexibility of the lumbar and thoracic spine (Patterson et al., 1997). However, for practical application we do not consider this dubiety important, as both reckon to be important for prone paddling position (Mendez-Villanueva & Bishop, 2005). We propose that the arched position on the surfboard allows the surfers to be sufficiently forward and thus reduces the drag forces acting on the surfboard. This can be also beneficial when the wave approaches the surfer, and based on the position of the surfer, gravitational force will make a difference whether the wave will be ridden or will pass over the surfer. With regard to research of Sheppard et al. (2013) comparing high and low chest position during sprint paddling, our perspective, alteration of anteroposterior position of surfer, was not considered. Our results showed a similar effect pattern compared to the SMBT outcome. Performance increased in all groups, however, with no statistical significance. The novel stimulus, the core stability training, seems to contribute to these findings. The only convincing results were in females. In our eyes, core stability training has made a significant contribution to improving their performance. Further, the normative table shows that expected values for adults ranges between 22.8 - 30.5 cm (Johnson & Nelson, 1986). Another interesting result was spotted in a group of experienced surfers. Almost negligible improvement after intervention and generally lower performance are characteristic for this cohort. Based on this, we suggest that better TLT values are not related to the surfing experience and core stability training does not affect results of experienced surfers.

CKCUEST is field, inexpensive, easy, quick to administer or interpret the test with trial-to-trial reliability (ICC=0.962) and test-retest reliability (Rho=0.9) (Borms & Cools, 2018; Hollstadt et al., 2020). In our view, the profile of this test is comparable to that of sprint paddling. The athlete, during a short period, coordinates symmetrically moving arms with increased effort to stabilize the upper body and trunk. The utilization of CKCUEST was reported in overhead sports with the following results. Players of volleyball within the same age to our samples (27.4 ± 2.5 [males], 18.9 ± 5.2 [females]), tennis (28.3 ± 3.5 [males], 20.3 ± 2.7 [females]), handball (27.0 ± 2.4 [males], 21.5 ± 4.2 [females]) (Borms & Cools, 2018) and basketball (29.5 ± 4.78 [males], 24.9 ± 5.52 [females]) (Hollstadt et al., 2020). It is important to mention that in the studies concerning the volleyball, tennis, and handball players average of three trials was presented, while methodology of Hollstadt et al. (2020) is not quite transparent, unless basketball players performed just one trial. Our results consider for statistical processing the best trial of the three. The gender comparison of our samples confirms previous findings, but no difference was found between beginners and experienced surfers. With regard to intervention, statistical analysis revealed a significant difference between evaluation in all groups studied. For this reason, we suggest that core stability training was effective and thus improved performance within CKCUEST. However, we also take into account the conclusion of the test-retest reliability study. Basketball players improved after one week, but the difference was not so considerable like in our case. Lastly, a shortcoming of our methodology is the utilization of the original CKCUEST, whereas the authors did not account for differences in shoulder width and/or arm length. Taylor et al. (2016) modified the initial position so that athletes start with palms placed beneath the shoulders, similar to a push-up position. Satisfactory reliability results have already been reported in basketball players (Hollstadt et al., 2020).

The final test, SUT, reflects the ability to stabilize the anterior abdominal wall together with the strength and power of the hip flexors. We believe in importance of trunk stability in sprint paddling performance, as the drag force applied to the surfboard may affect maximal velocity and thus decrease chances to be fast enough and catch a wave. The effect of hip flexors on sprint paddling is a topic to discuss; unfortunately, no studies have been performed yet. Our point of view is that during final strokes, athletes kick to produce propulsion forces. We analysed slow-motion video of world elite surfers and find a typical movement stereotype (Rose, 2018). Athletes stretch the anterior myofascial chain, so the upper limb is in the pushing phase of the paddling stroke and the contralateral knee is flexed (Wilke et al., 2016). Shortening the chain by pulling the arm simultaneously with hip flexion and knee extension creates momentum to successfully catch the wave and pop up on the surfboard. To sum up, this is just a theory that needs to be further investigated. Next, we noticed that the intervention affected almost all examined groups, except females. However, statistical significance was established only in the group of males. Lastly, with regard to the normative tables of Davis et al. (2000) for young adults, a group of men and women reached the performance that was characterized as 'Above average' (26-30 [males], 21-25 [females]). If we take into account the experience, the improvement of beginners also corresponded to superior performance (compared to normative data for men). A slight difference separated the group of experienced surfers from being in the same performance group as the other cohorts. The post-interventional value is 25.4 ± 3.9, which ranks them in the “Average” group (20-25 [for males]). Surfers appeared to show higher performance than average population and improved their outcome due to intervention, however, not significantly.

6.4 Study limits

Some constraints should be considered. First, when the subjects were characterized, the group we created counted 5 samples. For this reason, it is possible that a Type II error may have occurred (Faber & Fonseca, 2014). Second, the load applied to the samples may differ, as the training units had a different organization (individual, group, online). Third, the One-leg Stand test within the ALPHA-FIT showed to be an inappropriate tool to evaluate balance in surfers and hence should be substituted, for instance with the Y Balance Test - Upper Quarter (Borms & Cools, 2018). Fourth, one month is not a period sufficient to determine the impact of the intervention (Fetters & Tilson, 2018). Further research should consider a duration of at least 8-16 weeks. And the final limitation concerns the exercise protocol. Core stability depends on aerobic and anaerobic capacity (Butowicz et al., 2016). However, the published protocols do not focus primarily on development strength and power.

7 CONCLUSIONS

The discussion of the research results drew the following conclusions.

Based on our research findings, we have identified performance differences between genders and levels of experience. The velocity was higher in males, but this phenomenon was not the same for postural stability. For this reason, females should focus on developing this skill to substitute genetic disadvantage, generally lower strength. Also, in experienced surfers, we have found better postural stability than in beginners.

Unfortunately, injuries are inextricably linked to the sport of surfing. Among our samples, we have found ten injuries. However, scientific research is scarce on developing exercise programs to prevent injuries. Given the literature of our work, core stability training is effective in minimizing nontraumatic injuries. For this reason, we recommend the use of our exercise programme.

Core stability in sprint paddling is novel research that examines the training intervention on sprint paddling kinematics in the ocean environment. However, a few constraints have to be studied for further development. It is worth considering the comparison of fluid flow sensors and other evaluation tools to ensure reliable results. As by our observation, the values for velocity may vary. Next, the physiological demands for sprint paddling should be respected and the optimal length for the intervention. Although the velocity mainly remained unchanged, four weeks appeared to improve postural stability, however, not significantly. The groups who most benefited from the training were females and beginners.

The physical tests within this study were chosen to decide on a mechanism that could potentially affect functional paddling performance. CKCUEST was a crucial motor test in which all samples improved. Thus, improvement of sprint paddling is referred to this test and successful stabilization as an effect of training. The additional improvement as a result of the intervention was in females within TLT and SUT of males.

8 SUMMARY

This diploma thesis aimed to investigate the effects of a core stability exercise on surf sprint paddling performance. Among scientific research works, this topic is often studied to enhance the performance of athletes or reduce the incidence of injuries. In our case, it was expected that surf sprint paddling would improve after a physical therapy intervention to stabilise the trunk muscles, as was previously reported in various sports of overhead athletes.

Functional paddling was evaluated in the water and analysed with a fluid flow sensor attached to the surfboard. Subsequently, dry-land motor testing was carried out. One month was a period during which 15 subjects exercised twice a week. Two exercise protocols were created based on physiotherapy principles to improve the activation of deep stabilising muscles. The first protocol mainly focused on static isometric exercises, while there were characteristic functional movements for the second protocol. After completing four weeks of training, the subjects underwent the same evaluation.

The effect of the intervention was found in variables describing postural stability but not velocity. To decide whether postural control or stabilisation is crucial for sprint paddling has to be still decided. Our recommendation is to apply a more extended period of intervention and respect the sport-specific demands of surf sprint paddling when preparing the training protocol. Likewise, specific physical tests improved as a result of core stability exercises. These findings led us to decide on a potential mechanism that causes differences in the functional test, paddling. The disadvantage of the study is the choice of the One-Leg Stand test as a tool to identify the level of postural control. Future research should consider our findings and use a more elaborate method.

In general, our study presents some evidence of improvement in surf sprint paddling performance. For this reason, we suggest that physiotherapy-based core stability exercises can promote improvements in surfers regardless of gender and experience.

9 SOUHRN

Záměrem diplomové práce bylo prozkoumat vliv cvičení svalů stabilizujících trup na výkon při surfovém pádlování ve sprintu. Mezi vědeckovýzkumnými pracemi je toto téma oblíbené. Snahou vědců je zvýšení výkonnosti sportovců nebo snížení výskytu zranění. V našem případě jsme očekávali, že po fyzioterapeutické intervenci zaměřené na stabilizaci trupových svalů dojde ke zlepšení výkonu surfového pádlování. Vycházeli jsme ze studií, které již prokázaly účinnost takto specifického tréninku u sportovců praktikující tzv. overhead sporty.

Funkční testování (pádlování) bylo provedeno ve vodě za použití tzv. fluid flow senzoru, který byl součástí surfovacího prkna. Poté účastnicí absolvovali fyzické výkonnostní testy na souši. Intervence trvala jeden měsíc, během tohoto období 15 subjektů cvičilo dvakrát týdně. Pro účely výzkumu byly vytvořeny dva cvičební protokoly založené na fyzioterapeutických principech pro zlepšení aktivace stabilizačních svalů. První protokol byl většinou zaměřen na statická izometrická cvičení, zatímco druhý protokol byl charakteristický funkčními pohyby. Po absolvování čtyřtýdenního tréninku byli účastníci výzkumu opět změřeni identickými testy.

Efekt intervence byl zjištěn u proměnných popisujících posturální stabilitu, ale ne u rychlosti. Rozhodnutí, zda je pro surfové pádlování ve sprintu klíčová posturální kontrola nebo stabilizace, nelze ještě s jistotou stanovit. Naším doporučením je však při přípravě tréninkového programu zvolit delší dobu intervence a respektovat fyziologické nároky odpovídající surfařskému sprintu. Dále, podobně jako u funkčního testování, se zlepšily výsledky specifických fyzických testů v důsledku intervence. Tato zjištění nás vedla k rozhodnutí o potenciálním mechanismu, který způsobuje rozdíly ve funkčním pádlovacím testu. Nevýhodou studie je volba testu stoj na jedné končetině jako nástroje k identifikaci úrovně posturální kontroly. Budoucí výzkum by měl zvážit naše zjištění a použít propracovanější metodu.

Obecně lze tvrdit, že naše studie přináší určité důkazy o zlepšení výkonu surfového pádlování ve sprintu. Z tohoto důvodu naznačujeme, že cviky využívající běžné fyzioterapeutické postupy mohou podpořit výkon surfařů bez ohledu na pohlaví a zkušenosti.

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11 LIST OF APPENDICES

SURF | RESEARCH | PHYSIOTHERAPY

WILL CORE STABILITY TRAINING AFFECT PERFORMANCE IN SURFERS?

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[4] Laboratory (LABIOMEP-UP), University of Porto, 4200-450 Porto, Portugal

INTRODUCTION

The science applied to surfing faces a narrow participation of physiotherapy. Despite the possibility to propose new insights on current knowledge, and thus enrich sport science by multidisciplinary approach. The aim of this work was to develop a core stability training program and verify its potential efficiency using sprint paddling-specific test battery (TB).

OBJECTIVES

- Create surf-specific questionnaire
- Develop a battery of tests
- Analyse the effect of intervention

FIG.1

METHODS

Field experiment with exploratory design was applied in the group of 15 surfers. 10 males (age: 29.1 ± 5.9 years, weight: 77.2 ± 8.5 kg, height: 181.2 ± 8.1 cm) and 5 females (age: 28.4 ± 4.6 years, weight: 61.8 ± 3.1 kg, height: 165.6 ± 2.9 cm). TB (Fig.1) was utilised to collect data prior the initiation of training and consisted of five consecutive tests related to demands of sprint paddling. Seated medicine ball throw (SMBT) analysed arm pushing power, One-leg stand test (OLST) examined postural control, Trunk lift test (TLT) back strength and flexibility, Closed kinetic chain upper extremity stability (CKCUEST) focused on stability of the upper body (Fig. 2), Sit-ups test (SUT) evaluated abdominal strength and power. The 4-week intervention of two dependent exercise units was subsequently applied. Within the first exercise unit the surfers performed isometrical contraction of core stabilisers to maintain the position, while second contained whole-body movements with an emphasis on precise execution. Inclusion of breathing techniques was targeted to enhance diaphragm activation. The subjects were led by a physiotherapist individually or in a group of max 4 people. Initially, the body was expected to adapt for a new stimulus and subsequently increase muscle capacity over the next sessions by application of resistance against movement or strict control of the exercise position. At the end of the intervention each participant underwent a final evaluation and received an evaluation protocol (Fig.3). For the entire period International Physical Activity Questionnaire (IPAQ) was used as a variable to monitor movements. Descriptive statistics and correlation were used to describe the results.

FIG.2

RESULTS

The best of 3 trials was selected for each test. Horizontal distance of SMBT (PRE: 568 ± 143.4 cm, POST 592 ± 128 cm), vertical measure of TLT (PRE: 28 ± 6.2 cm, POST: 30 ± 7.9 cm), repetitions of CKCUEST (PRE 26 ± 3.4, POST 31 ± 4.5) as well as in SUT (PRE 24 ± 2.2, POST 26 ± 4.2). Entire group reached the maximum in OLST. The correlation values for comparison differences of max. PRE, POST trial and total MET/min/month, except the OLST, are as follows (r_{SMBT}=0.13, r_{TLT}=0.49, $r_{CKCUEST}$=-0.36, r_{SUT}=0.5, r_{mean}=0.19).

SPECIFIC EVALUATION

SMBT [cm] PRE 790 POST 717; CKCUEST [N] PRE 31 POST 40; TLT [cm] PRE 30 POST 35; SUT [N] PRE 28 POST 32

FIG.3

CONCLUSION

Superior performance in post-evaluation suggests the effectivity of the physiotherapy-based training protocol. The authors' curiosity considers interesting to assess sprint paddling in water to support decision-making on performance indicators and to evaluate the effect of the intervention from the perspective of kinematic analysis. Lastly, our findings suggest replacement of OLST by more appropriate tool.

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Figure 38. SCS 4th Annual Conference on Strength and Conditioning for Human Performance in Porto 12th to 13th November

U.PORTO
FACULDADE DE DESPORTO
UNIVERSIDADE DO PORTO

SCS
STRENGTH & CONDITIONING SOCIETY

CERTIFICATE OF PRESENTING AUTHOR

This is to certify that
Musil Vit

Presented the following Poster at the
SCS 4th Annual Conference: Strength and Conditioning for Human Performance

Held in
Porto, 12th – 13th November 2021

With the title
WILL CORE STABILITY TRAINING AFFECT PERFORMANCE IN SURFERS?

Co-Author(s)
Musil Vít, Vilas-Boas João Paulo, Borgonovo-Santos Márcio

SCS President
Prof. Pedro E. Alcaraz, PhD, CSCS, NSCA-CPT

Figure 39. Certificate of presenting author

Figure 40. Performance protocol of specific evaluation for study participants

Figure 41. Poster for IJUP (Investigação Jovem da Universidade do Porto)

ENCONTRO
INVESTIGAÇÃO JOVEM

14.ª EDIÇÃO

5.6.7. MAIO 2021

CERTIFICADO

Certifica-se que Vít Musil participou no **IJUP'21 – 14º Encontro de Investigação Jovem da Universidade do Porto**, que decorreu nos dias 5, 6 e 7 de maio de 2021, tendo apresentado o *e*-poster com o título "Core stability exercise protocol for pilot study initiation".

Vice-Reitor
Pedro Rodrigues

U.PORTO
Santander Universidades

Figure 42. Participation certificate

Date: EXPERIMENTAL | CONTROL Ref. code:

SPECIFIC TESTS – EVALUATION SHEET

Name:______________________________

Birth date:___________________________ Gender: ☐ male, ☐ female

Weight:_____ Height:_____ Arm span:____ Shoulder width:______

PRE – INTERVENTION

	TRIALS	ERRORS		TRIALS	ERRORS
SMBT:	1.		CKCUEST:	1.	
	2.			2.	
	3.			3.	
OLST:		DOM:	SUT:		
MPUT			NOTES:		
TLT:	1.				
	2.				
	3.				

POST – INTERVENTION

	TRIALS	ERRORS		TRIALS	ERRORS
SMBT:	1.		CKCUEST:	1.	
	2.			2.	
	3.			3.	
OLST:		DOM:	SUT:		
MPUT			NOTES:		
TLT:	1.				
	2.				
	3.				

OBSERVATION:

Faculty of Physical Culture RIEDEL U.PORTO

Figure 43. Specific evaluation protocol - record sheet

FUNCTIONAL TESTING PROTOCOL – sprint paddling

WARM – UP

3 min light intensity continuous paddling

1.5 min out of the port, WHISTLE, 1.5 back

2 min ALL OUT = SPRINT PADDLING

5 sec, WHISTLE, 30 sec REST

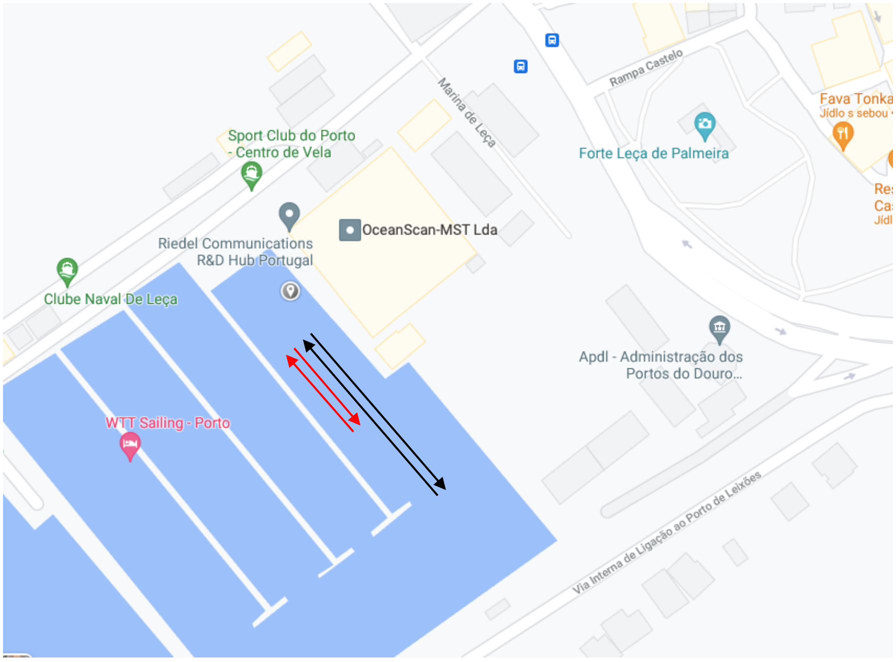
WHISTLE 5 sec, WHISTLE, 30 sec REST

WHISTLE 5 sec, WHISTLE,

5 -10 min REST (another subject doing same procedure)

TESTING

3 X 20 sec ALL OUT, WHISTLE, 5 min REST (after each trial subject rests and another participant is being tested), designed for 3 persons



Notes: STOPWATCH, TIME, PEN, PAPER, WHISTLE, SURFBOARD

NOTE REAL TIME OF EACH TRIAL

NOTE WIND SPEED, DIRECTION AND DATE

Figure 44. Functional testing protocol - support sheet

Fakulta
tělesné kultury

Vyjádření Etické komise FTK UP

Složení komise: doc. PhDr. Dana Štěrbová, Ph.D. – předsedkyně
Mgr. Ondřej Ješina, Ph.D.
doc. MUDr. Pavel Maňák, CSc.
Mgr. Filip Neuls, Ph.D.
Mgr. Michal Kudláček, Ph.D.
prof. Mgr. Erik Sigmund, Ph. D.
doc. Mgr. Zdeněk Svoboda, Ph. D.

Na základě žádosti ze dne 11.2.2021 byl projekt diplomové práce

autor /hlavní řešitel/: **Bc. Vít Musil**

s názvem: **Vliv cvičení stabilizačního systému trupu na rychlost při surfovém pádlování**

schválen Etickou komisí FTK UP pod jednacím číslem: **47/2021**

dne: **15. 3. 2021**

Etická komise FTK UP zhodnotila předložený projekt a **neshledala žádné rozpory** s platnými zásadami, předpisy a mezinárodními směrnicemi pro výzkum zahrnující lidské účastníky.

Řešitel projektu splnil podmínky nutné k získání souhlasu etické komise.

za EK FTK UP
doc. PhDr. Dana Štěrbová, Ph.D.
předsedkyně

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Figure 45. Statement of the ethics committee

Faculty of Physical Culture

INFORMED CONSENT

Project: VALIDATION OF A CORE STABILITY EXERCISE PROTOCOL TO IMPROVE SURF SPRINT PADDLING PERFORMANCE

Name:

Date of birth:

Participant's reference: **(e.g. Vít Musil = MUSVIT)**

1) I, the undersigned, agree with my participation in the study. I am over 18 years old. In case of minor, I am represented by my Legal Representative or Guardian (LR/G).

2) I was informed in detail about the aims of the study, its procedures and what is expected from me. I acknowledge that the study being conducted is research activity. If the study is randomized, I acknowledge the likelihood of randomization to different groups.

3) I understand that I may suspend or withdraw from the study at any time. My participation in the study is voluntary.

4) I am promised that my personal data will be kept with full protection of confidentiality according to the General Data Protection Regulation (GDPR) based on Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC
During the actual implementation of the study, personal data may be provided to entities other than those listed above only without identification data, ie. anonymous data under a numeric code.

5) I understood that my name would never appear in papers about this study. On the contrary, I will not oppose the use of the results in this study.

6) At the same time, I consent to the taking of photographs/videos during the research. The material will be used for a presentation of the study.

Proband's signature or LR/G: Data collector:

Date: Date:

Figure 46. Informed consents for participants in the project