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Musculoskeletal injuries in Portuguese junior elite surfers: an epidemiological and fitness exploratory study

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Abstract:
Background*: Surfing requires control of physical skill-demanding actions that also involve adaptations to the surrounding environment (winds, currents and wave size), in order to guarantee successful manoeuvres. This study aimed to identify the prevalence of musculoskeletal injuries in top competitive junior Portuguese surfers, to characterize its occurrence pattern, and explore the potential associated risk factors related to their physical fitness and complementary training performed.*
Materials and Methods*: All surfers from the National Portuguese Junior Surfing Team (n=28; 22 Male, 6 Female), aged <18yrs old, filled a questionnaire related to injury occurrence over the past 9 months and complementary training routines, and performed 3 physical tests (Knee-to-wall test, Y-balance test and Sit & Reach test).*
Results*: There was a low Injury Prevalence (IP) of 0.25, in which injured junior surfers had "more than 9 years of practice", being lower limbs the most affected area (62,5%: knee, ankle and leg), with majority of the injuries sustained "during a surf training session" (75%), "performing a manoeuvre" (50%), resulting in a time-loss of "more than 30 days" (100%). Physical tests were within the reference values and not related with injuries.*
Conclusion: *Musculoskeletal injuries in junior elite Portuguese surfers, occur more frequently in lower limbs, while performing manoeuvres, and represent a high time-loss (> 30 days). In future, longitudinal studies are needed to investigate training workloads and tasks, as well as injury prevention strategies in order to optimize performance and reduce injury risk to the lower limbs.*
Key Word*: injuries; risk factors; prevalence; young surfers; injury prevention*

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I. Introduction

Surf is a discipline of surfing which is a sliding sport and that consists on wave riding, towards the beach. Its expression is the level of the (technical) manoeuvres performed during the gliding of the board on the wave[(1)]. It is a growing sport, and the latest studies suggests that there are 35 million surfers worldwide, in at least 162 countries[(2),] and according to the Portuguese Surfing Federation (FPS), in 2019 there were 750.000 amateur surfers and 2000 federate surfing athletes in Portugal.[(3,4).]

It is also an activity characterized by intermittent exercise bouts of varying intensities and durations involving different body parts (ex. paddling – upper body vs wave ridding – lower body) and numerous recovery periods[(5).] Competition specifications require performing 20-40min surfing heats, concerning a submaximal exercise of up to 1km paddling (aerobic energy system) and short powerful bursts of 4-5 seconds to catch the wave before riding it (anaerobic energy system), resulting in moderate (140 bpm) to high (190 bpm) heart rates[(6)].

Besides all physical demands requires, like the high muscular endurance and anaerobic power of the upper torso, excellent cardiorespiratory fitness, and the ability to recover rapidly[(6)], plus the intrinsic abilities that characterize the surfers physical condition (e.g. coordination, balance, flexibility, strength, training level…), there are several external factors related to this activity (practice time, wind orientation, type of seabed, wave size, the use of protective gear,..), that influence the surfers ability and performance[(1,7,8).]

Although surfing equipment is constantly evolving, also to ensure protection form the surrounding environment (*e.g.* booties to protect from reef lacerations, helmets to prevent head trauma, warmer wetsuits to ensure proper thermoregulation, surfboard leashes to protect surfers from being hit by others' surfboards during wipeouts[(9)]), over the last years surfing itself as also evolved in its domains, highlighting Big Wave Surfing, wave pools and aerial manoeuvres, which may expose surfers to new and higher risks. The judging criteria of the World Surf League to score a wave is based on "*Commitment and degree of difficulty; Innovative and progressive manoeuvres; Combination of major manoeuvres; Variety of manoeuvres; Speed, power and flow*"(10). Although injury rates in competitive surfing are low when compared to other sports(11), surfing as its share of injury risk probability, as during competition the surfer as to successfully perform high-risk manoeuvres, such as tubes, floaters, and aerials to ensure the highest possible score on each wave performed(12,13).

Type and location of injury

The unpredictability and variability of environment constraints oblige a complex decision-making process, difficult manoeuvres endings or landing tasks. Studies based on hospital emergency records tend to reveal high frequencies of lacerations / cuts, especially in the head and leg regions(14,15); However, research outside the hospital or emergency environment reveals a greater number of musculoskeletal injuries like soft tissue sprains and strains, which are mainly represented in the lower regions of the body(7,13,16).

The 2020 systematic review by McArthur *et al*.(11), concerning the epidemiologic of surfing injuries, based on worldwide online surveys and health care facilities data concerning competitive and recreational surfers, showed that the most common type of injury was to the skin representing 46% of total injuries, followed by soft tissue injuries (22.6%) and bone injuries (9.6%), whereas in the emergency context, skin injuries represent 50.1% of surfing injuries, followed by soft tissue injuries (17.6%) and bone injuries (11.9%).

However, Nathanson *et al.*(15) indicate the lower extremities as the most common location (39%) for surfing injuries among competitive surfers, with 44% of them being sprains and strains.

After 2005, with an higher rate of aerial manoeuvres, lower-extremity injuries became the most frequent(13,17), with the knee (28%) and ankle (26%) at the top of the list, based on the fact that ankle sprains injuries increased considerably, from 6% (before 2005) to 26% (after 2005), as the latest study that characterizes competition surfing injuries among the world surf elite clearly demonstrates(13). Lundgren *et al.*(18) also referred that among all surfing injuries, about 40% occur in the lower extremities, mainly to the ankle and foot regions (15-20%).

Mechanism of injury and Injury rate

According to some studies(7,9,13,19), the most common mechanism of injury is the direct impact of the surfboard, which reinforces the idea that lacerations are the most common type of injury. However, most of these studies report broad categories of injuries rather than specific diagnoses and focused more on the direct impact of the surfboard as the primary injury. Hohn *et al.*(13) also point out the high impact injury patterns, rotation/ torsion related to ankle injuries, variables that we can associate with the execution of aerial manoeuvres.

More recently, McArthur *et al.*(11) systematic review also points out being hit by their own surfboard as the main cause of injury (38.5%), followed by approaching a wave or performing a manoeuvre while surfing (20.3%) and striking the seafloor or sea surface (18.4%).

As to the injury incidence rates (nº injuries per 1000h of surfing), they tend to be higher in competitive (0.42) than recreational (0.35) surfing, being aerialists the most prone to sustain injuries (0.48)(17).

Physical fitness, performance and injury

In surfing sport, high performance levels are related with factors as high levels of muscular strength, power, endurance power, dynamic postural control, and the ability to respond to the challenging situations during competition or free surfing(5).

It seems surfing athletes that exhibit greater lower-body isometric and dynamic muscular strength, and power also perform higher scoring turning manoeuvres during wave riding(20). Therefore, considering surfing a skill-based sport, physical abilities might be determinant to make it to the surfing elite(12).

Besides strength, dynamic postural control is also key as it there's a relationship between the postural skills and the competition level of surfers, whereas postural tests can be useful, not only to control the effectiveness of training sessions and prevent the loss of performance abilities (e.g., overtraining)(21), but also to identify chronic ankle instability and predicting injuries(22).

Moreover, because high velocity change of direction, landing and compression characterize some of the surfing manoeuvres, (*e.g.* aerials), joint range of motion limitation, specifically to ankle joint, may inhibit the performance of certain movements required to become a successful professional surfer, as it may also put the surfer at risk for lower extremity joint injury, unless proper development of strength and flexibility is implemented(18).

Therefore, the aim of this study was (1) to calculate the prevalence of musculoskeletal injuries in top competitive junior Portuguese surfers during a 9-month period and characterize its occurrence pattern like type, anatomical location, mechanism of injury and time-loss; and (2) to explore the potential associated risk factors related to their physical fitness and complementary sports activities performed.

II. Materials And Methods

This epidemiological, cross-sectional and exploratory study was conducted to gather information on junior elite Portuguese surfing athletes, concerning injury occurrence issues in the past 9 months, corresponding to one competitive season.

Study Design: Epidemiological, cross-sectional and exploratory study
Sample size: 28 athletes.
Subjects & selection method: Sample corresponded to the population, being all surfers from the National Portuguese Junior Surfing Team (NPJST: n=28; 22 Male, 6 Female), aged <18yrs old, which anthropometric characteristics are shown in Table 1.

Table 1: Anthropometric measures (M±SD) of the National Portuguese Junior Surfing Team.

	Boys (n=22)	Girls (n=6)
Age (years)	15.8±1.3	16.5±0.8
Height (cm)	168.9±6.7	163.3±4.2
Weight (kg)	59.7±9.4	56.9±5.4
BMI (kg/m^2)	20.8±2.1	21.3±1.9

BMI: body mass index

As to demographics related to surfing, in terms of surfing stance on the surfboard, there were 16 surfers (57,1%; 12 boys, 4 girls) in the regular position and 12 (42,8%; 10 boys, 2 girls) were goofy. Concerning the years of surfing practice and the age at the starting of competitions, as shown on Table 2, all surfers had at least 3 to 5 years of practice, meaning that 26 out of 28 surfers (92,9%) with an average of 16 years-old had at least 6+ years of practice. It is also shown that the surfers participating in this study started competing between 8 and 13 years-old, being 22 out of 28 (78,7%) started before age 11.

Table 2: Years of surfing practice and competing starting age

Years of surfing practice	N (%)	*Competing starting age*	N (%)
		8 years old	2 (7,14%)
Between 3 and 5 years	2 (7,1%)	9 years old	5 (17,8%)
Between 6 and 7 years	8 (28,5%)	10 years old	5 (17,8%)
Between 8 and 9 years	10 (37,5%)	11 years old	10 (37,5%)
More than 9 years	8 (28,5%)	12 years old	5 (17,8%)
		13 years old	1 (3,5%)

Inclusion criteria:
1. Competed national and /or regional surfing contests for the 2019 competing season;
2. Being eligible for the Junior National Surfing Team for the 2019-2020 period.

Exclusion criteria:
1. Not having sustained a musculoskeletal injury that prevent the surfer to perform any of the physical tests required for this study before;
2. Still recovering/ rehabilitating from injury

Procedure methodology

Approval for this study was obtained in June 2018 by the ethics committee of Escola Superior de Saúde Atlântica (ESSATLA) review board. As all subjects were minors, an informed consent was given/delivered and signed by the athlete's parents, guaranteeing permission to participate in the study.

Information was collected during a National Junior Surfing (questionnaires and physical fitness tests) Team Internship gathering, prior to any physical activity/ surfing session, in order to prevent eventual bias from fatigue before the physical tests. However, all participants performed a 5min warm-up drill exercises to the main regions/ joints of the body.

Anthropometrics: Body height and weight were measured to the nearest 0.5 cm (mobile stadiometer with integrated level Seca 213), and 0.1 kg (digital flat scale Seca 803) respectively, before the tests performed. Height was measured with the athlete barefoot, feet together, and head level[12], as weight was measured with the athlete being only with in board shorts (plus tank top in girls), and barefoot. Body mass index (BMI) = body mass (kg) / body height (m2) was also calculated for each athlete.

Injury prevalence and occurrence pattern: A questionnaire intituled "Musculoskeletal injuries in Portuguese junior elite surfers", adapted from the Minghelli's questionnaire[8] was composed by a socio-demographic characterization (name, age, gender, team name, stance, years of practice and age at competitive surfing initiation and complementary sports activities); and injury occurrence over the past 9 months (number of injuries, location, mechanism and time-loss due to injury). Injury was defined as "*any condition or symptom occurred as a result of surfing, with at least one of the consequences: a) stop surfing activities (free surfing, training or competition) during at least 1 day; b)produced an alteration in surfing related activities (e.g. less time of practice, less effort intensity, less ability to perform certain technical gestures or manoeuvres); c)seek healthcare advice or treatment to solve that condition or symptom"*[8].

Physical fitness tests: as Henriques-Neto *et al.*[23] refer that to improve physical performance, identify talents and develop injury prevention programs, physical fitness monitoring is essential. Therefore, a selection of tests was made considering, not only previous studies[12,18,23–25] which evaluated junior populations on their physical capabilities, as well as some others which refer the increasing number of injuries to the lower limbs in surfing[13,15,17,18], especially after 2005 when the aerial manoeuvres became more popular among professional surfers[13,17].

Maximum ankle dorsiflexion was assessed trough the weight bearing *knee-to-wall test (KW)* (expressed in centimetres), and *goniometry* (in degrees) in the same position. Both tests were performed with the subject in a short lunge position with the front knee projected forward with the subject trying to reach the wall. The maximum distance between the tip of the first metatarsal of the great toe and the wall when the subject could reach their knee to the wall was measured. The recordings of KW and goniometry were made for the front and rear foot in the surf-stance, as some surfers stand in in a *'natural'* position (left foot forward), and others in a '*goofy'* position (right foot forward)[18], and to ensure validity ($p<0.05$) and reliability (ICC: 0.93–0.99) of 1.0/1.5cm for minimum detectable change (MDC) between limbs[26].

The *flexibility of the lower back and hamstrings* was assessed through the *Sit & Reach test*, which showed acceptable reproducibility measures (ICC: 0.92)[24] and validity measures (r= 0.7 to 0.76; $p<0.05$)[27] and that is commonly used in several sports (*eg.* Basketball, football, gymnastics, judo, swimming, weightlifting, etc.) to assess flexibility[23]. Participants performed the forward flexion movement of the trunk with both arms extended, one leg bent at 90º and other leg extended touching with the sole of the foot on the measurement box. For this test, the mean value from the two legs was calculated and considered for the data analysis[23].

Coordination, dynamic balance and postural control were assessed using the *Y-Balance Test Lower Quarter (YBT)*, with the Y Balance Test™ kit, that has demonstrated suitable validity[25] and intra-rater reliability (ICC: 0.85-0.91)[28]. The subjects were barefoot during the test and must be with the tested foot placed and aligned with the edge of YBT stance plate, leaning against the starting line[29]. To perform this test, while maintaining single leg stance on one foot and the hands on this waist, the subject reaches the anterior, posteromedial and posterolateral directions with the free limb, in relation to the stance foot by pushing the indicator box as far as possible[30]. Subjects completed 3 consecutive trials for each reach direction and attempts were discarded and repeated if the subject failed to maintain unilateral stance on the platform, failed to maintain reach foot contact with the reach indicator on the target area while the reach indicator is in motion, used the reach indicator for stance support, or failed to return the reach foot to the starting position under control[29,30]. Normalising scores were considered to analysis, relative to the subject's limb length (measured in centimetre, with a tape measure), by calculating the summing of the individuals reach distance and dividing by the limb length, then multiplied by 100 to be expressed as a percentage[22,25]. Normalized composite reach distance (sum of the maximum reach distances - in centimetre - in the 3 directions, divided by 3 times the limb length, and then multiplied by 100) and limb reach asymmetry (difference between both legs reach distance in the anterior direction) were also computed. An asymmetry equal or greater than 4 centimetres and/or composite score less than 94% is associated to poor neuromuscular control and increased risk of lower-extremity injury[25, 31].

Statistical analysis

In order to characterize our sample, descriptive statistics (average, median, standard-deviation) and frequencies were used, according to the variables involved. Prevalence estimates were obtained through relative frequencies. Comparison between injured (INJ) and non-injured (N-INJ) athletes were carried out whenever the distribution conditions allowed it, using Student's t-Test, and alternatively, using the Mann-Whitney non-parametric test. The assessment of distributional conditions was made through the Shapiro-Wilk normality test.

Significance level used for all tests was p<0,05 and statistical analysis was computed with Microsoft Excel (v 16.44, 2010) and Statistical Package for the Social Sciences (v 27.0; SPSS Inc.).

III. Result

The results that follow correspond to the data collected at the NPJST internship gathering *a)* from the injuries questionnaire, and *b)* from the physical fitness tests.

a) Injuries questionnaire

Population characterization was made through a questionnaire concerning demographics, surf training characterization and injury prevalence.

Considering the under-18 NPJST, boys (n=22) and girls (n=6), in terms of *injury prevalence*, only 7 out of the 28 surfers (25%) suffered 1 injury, with only 1 participant referring 2 injuries (8 injuries total), during the last competitive season (previous 9 months). The lower limbs were the most affected area (n=5; 62,5%: knee, ankle and leg), followed by the shoulder (n=2; 25%), and the thorax (n=1; 12,5%).

From the different comparisons made, considering *Age* difference, we verified N-INJ athletes were 15.76±1.26 years-old and INJ athletes were 16.71±1.11 years-old, which was not statistically significant (t (26) =1.776, p>0.05). As to the *Years of Surfing*, the difference was statistically significant (U=30.5, p=0.023), with the N-INJ reporting "8-9 years of practice", and the INJ group reporting "more than 9 years of practice".

Regarding the *mechanism of injury*, concerning the moment of occurrence and wave height, for those 8 injuries, the majority of them was sustained "during a surf training session" (n=6; 75%), in a wave measuring from 0,5 to 1,0 meters (n=3; 37,5%), while "performing a manoeuvre" (n=4; 50%), resulting in a time-loss of "more than 30 days" (n=7; 100%).

In terms of *injury prevention*, the majority of the surfers (n=15/28; 53,6%) does not perform any kind of "injury prevention training". However, the ones who did it focus this type of training "mainly to the lower limbs" (n=12/28; 42,9%).

Regarding surfing *complementary sports activities*, 27 out of the 28 surfers (96,4%) reported to perform some kind of complementary sports, at least "3 times per week" (n=22; 81,5%), being the "gym" the place where it occurs more often (n=23; 85,1%).

Considering the INJ athletes group, all of them (n=7; 100%) did some kind of complementary sports, and 4 out of 7 (57,1%) did injury prevention training directed to the lower limbs, being the "gym" and "3 times /week" the location and frequency of training most commonly reported as well.

b) Physical fitness tests

Physical fitness tests were performed regarding maximum ankle dorsiflexion, flexibility of the lower back and the posterior muscles of lower limbs, and dynamic balance/ postural control.

Maximum ankle dorsiflexion, revealed to be the identical for all the 28 surfers, for both ankles, whether it was assessed with the KW (left ankle=11.5±3.2cm; right ankle=11.6±2.7cm) or by measuring the dorsiflexion of the ankle with goniometry while performing the same weight-bearing lunge movement used in the KW (left ankle=37.1±5.3º; right ankle=37.1±5.1º);

As for the *flexibility of the lower back and hamstrings*, assessed with the *Sit & Reach test*, 16 out of 28 surfers (57.1%) overcame the sample mean score of 23.7±8.4cm, with the scores ranging from 5 to 37cm.

Concerning *dynamic balance/ postural control*, the YBT was used to calculate the reach distance, expressed as a percentage of the leg length (%LL), and as Table 3 shows, the athletes demonstrated a higher percentage for the postero-medial direction (127.7±7.8%), followed by the postero-lateral (122.1±7.6%), and the lowest result for the anterior direction (82.1±7.4%).

Table 3: Values of the YBT - expressed as a percentage of the leg length (%LL)

	Anterior		*Postero-Medial*		*Postero-Lateral*	
	Right	Left	Right	Left	Right	Left
	82.5±6.1	81.6±8.6	130.5±8.0	124.8±6.4	119.9±7.5	124.3±7.1
Average	82.1±7.4		127.7±7.8		122.1±7.6	

As for the comparison of *Injured/ Non-injured and Physical fitness tests performance* (Table 4) our results showed that all measures are very similar between both INJ and N-INJ groups and are not statistically different (p>0.05).

Table 4: Comparison between Non-Injured/ Injured surfers AND Fitness Tests

	Non-Injured (n=21)			Injured (n=7)		
Fitness Test	*Mean*	*ST-Dev*	*Median*	*Mean*	*ST-Dev*	*Median*
KW-Left (cm)	11.53	3.35	11.7	11.50	2.88	11.6
KW-Right (cm)	11.63	2.67	11.7	11.54	3.10	11.6
Goniometry –Left (º)	37.27	5.73	37.50	36.67	4.08	37.50
Goniometry –Right (º)	37.60	5.26	38.57	35.83	5.85	35,00
Sit & Reach (cm)	24.84	7.46	25.30	20.28	10.80	24.30
YBT – Anterior Left (%)	82.82	9.04	81.48	78.00	6.48	76.32
YBT-Postero-medial Left (%)	125.89	6.56	127.61	121.89	5.37	120.61
YBT – Postero-lateral Left (%)	124.34	7.17	125.93	124.24	7.48	121.85
YTB Composite Left (%)	111.01	6.43	111.80	109.01	6.12	105.20
YBT -Anterior Right (%)	82.71	6.62	81.89	82.02	4.55	83.33
YBT-Postero-medial Right (%)	129.82	7.96	130.38	132.69	8.51	132.96
YBT -Postero-lateral Right (%)	120.73	7.92	121.81	117.54	5.93	116.67
YBT Composite Right (%)	111.10	6.43	111.00	110.76	5.91	111.00
YBT Anterior Asymmetry (cm)	4.92	2.54	4.70	7.37	3.66	7.70
YBT Postero-lateral Asymmetry (cm)	4.39	3.47	3.70	5.57	3.80	4.70
YBT Postero-lateral Asymmetry (cm)	4.39	3.47	3.70	5.57	3.80	4.70

Abbreviations: KW: Knee-to-wall (measured in cm); YBT: Y-Balance Test Lower Quarter (measured as a percentage of the leg length - %LL); YBT Asymmetry in centimetres (cm); Goniometry in degrees (º).

IV. Discussion

This study is the first of a kind considering the entire National Portuguese Junior Surfing Team, and specifically addressing musculoskeletal injuries and its prevalence and associated factors.

Injury Prevalence

From the 28 surfers studied, only 8 injuries were reported by 7 surfers considering a 9-month period, which gives us an Injury Prevalence (IP - total injured athletes divided by total number of athletes) of 0,25. This low IP goes in line with Minghelli *et al.*[32] who also focused on Portuguese surfers (competitive and recreational; n=1016; 8-64 years-old) and showed an IP of 0,29; Furness *et al.*[17] with an IP of 0,38 (recreational) to 0,42 (competitive) for Australian surfers (n=1348; 11-70 years-old); or even as Taylor *et al.* [14] study with an IP 0,26 (n=646; 18-64 years-old), even though all these studies were based on a 12-month period, for bigger samples and a wider age range.

Age & Years of surfing

In this study with junior population, age doesn´t seem to be a determinant factor to contribute to IP. However, and although it wasn't statistically significant, older surfers (>16 years old) were the most injured. Likewise, Costa e Silva *et al.*[33] results describe older federated sports adolescents (≥16 years old) as more prone to injury occurrence, and Jayanthi *et al.*[34] who also refer that injured young athletes are frequently older (≥14 years old) and spent more hours per week in organized sports, justifying that maybe as athletes get more specialized they may be more likely to push themselves harder to achieve their goals, and therefore, putting themselves in a higher risk of sustaining injury.

As to the years of surfing, although our small sample size, INJ athletes tended to be more experienced (>9 years of practice) than the N-INJ (8-9 years of practice). Although we didn't find any specific correlation in previous studies concerning IP and surfing experience, we can hypothesise that older surfers might be more prone to injures as they attempt more risky manoeuvres, as they get more experienced surfing bigger or more demanding waves, which require more control, increased reaction time or those specially related to landing skills, as aerials.

Body Area

Our results also show that lower limbs were the most injured region (62,5%), particularly the knee (n=37,5%) which differs from the 2020 McArthur's *et al.*[11] systematic review that describes lower limbs as the second most affect region (33%), right after Head/neck/ face (33.8%), probably because their review is related to data collected both in Emergency room and survey contexts, which took in consideration not only musculoskeletal injuries. However, when considering the 2018 Hohn *et al.* [13] study, concerning only professional (competitive) surfers, they refer the knee (28%) and ankle (22%) as the most affected areas. As they're study points out, this might be due to the inclusion of a new higher-risk and well rewarded manoeuvres in surfers´ repertoire in competition context – the aerials – since 2005. Minghelli *et al.*[8] also reported the knee and leg as the most injured body area (16,7%) in their study concerning 1016 Portuguese competitive and recreational surfers, as well as Costa e Silva *et al.*[35] referring that for different sports, the lower limbs as the most injured body area (53,8%) in Portuguese children and adolescents. Patel *et al.*[36] in their study concerning sports-related musculoskeletal injuries epidemiology, based on several national surveys in young athletes in United States also refer the lower extremities as the most commonly injured areas (42%).

Injury mechanism

Considering the mechanism of injury, most studies refer "being struck by own board" as the most frequent one [8,11,15,17], resulting mainly in cuts, lacerations or concussion [8,1115].

However, because our study was focused only on musculoskeletal injuries, its results are in line with the latest systematic review from McArthur's *et al.*[11], who also point musculoskeletal injuries resulting mainly from performed manoeuvres, and with Furness *et al.*[17] who refer surfing injuries predominantly as having a muscular (31,3%) or joint (28,7%) origin. This may also justify the time loss (days without being able to surf after sustaining an injury) of "more than 30 days" reported by all INJ, since maybe most musculoskeletal injuries take more time to treat and heal than, for instance, light concussions or cuts/ lacerations.

The difference from our results could be related with surfing levels/ experience and age because most of the referenced studies consider all kind of levels and a wide age interval. Being our sample with top junior surfers, the results might reflect that they are more able to control their surfboards, preventing them to hit them, making injuries more prone to occur while attempting more risky manoeuvres, like aerials.

Specifying more about the moment of occurrence, our results show that all injuries occurred "while performing a manoeuvre" (100%), "during surf training" (75%) and with a wave varying from "0,5 to 1,0 meters" (37,5%) being the most frequent height.

Maybe because most previous injury related surfing studies include recreational and competitive surfing, they do not inquire about the specific moment (training or competing) or wave height. However, these are also important factors to be considered when trying to characterize and establish associations concerning the injury mechanism of injury, because a landing manoeuvre (*e.g.*, floater, aerial) or a rotational manoeuvre (*e.g.*, cutback, snap) might have different implications in terms of impact forces and/or increased stresses on ligamentous and contractile tissues, applied specially to lower limbs joints that can result in severe injury. As an example, Furness *et al.*[17], reported the highest IP (0,48) in competitive surfers who could perform aerial manoeuvres.

As to *complementary sports activity*, all athletes except one reported some kind of sports activity besides surfing, varying from "gym" (85,7%), "skating" (28,5%), "swimming" (17,8%) and "running" (17,8%), but if any of those was part of a long-term athlete develop (LTAD) programme, was not clearly reported.

However, it seems that sports variety has not really prevented injuries in our sample, since all of the INJ athletes reported some preform kind of complementary sports activity and 57.1% of them even did "injury prevention training".

These findings, and the fact that "gym" isn't specific enough to characterize the type of exercises performed (e.g. strength, flexibility, sensorimotor training) and associated load utilized, may lead us to think that maybe the type of training loads or activities may not be totally suitable for these surfers, making it less effective for enhancing physical fitness and injury prevention purposes.

Regarding the *physical fitness tests*, although none of the following associations was statistically significant, they show a tendency for our sample. Considering the median values, both *KW* and *Sit & Reach* tests present only 1centimetre difference between INJ and N-INJ groups; weight bearing ankle goniometry presents less than a 3-degree difference between them, therefore, since there is a direct correlation between its validity and KW test and our study relies on a single evaluation moment, we chose not to draw definitive conclusions or establish associations, as solid correlations may not be accurate. According to our findings, for the KW test all the surfers presented similar average values (11.5±2.8cm to 11.6±2.6cm) to other junior-elite surfers studies addressing ankle ROM, like Dowse *et al.*[37] (10.0±2.0cm to 11.0±3.0cm) and Lundgren *et al.*[18] (13.9±2.8cm to 14.3±3.9cm), which was focused on ankle ROM among surfing athletes. According to Steele &

Sheppard[38], normal KW values range from 6 to 8cm, and may be higher for surfers (>12cm) or volleyball players (>15cm).

As for the *Sit & Reach* test, our athletes scores (INJ=20.2±10.8cm to N-INJ=24.8±7.4cm) were lower when compared with 138 Portuguese young athletes (26.6±9.8cm), aged 9 to 18 years old, from the Henriques-Neto *et al.*[23] study, which assessed they're physical fitness. A low score on this test is related to posterior muscles of lower limbs and spine stiffness and a higher predisposition to muscle injury, patella tendinopathy and lower back disorders, the results may also be influenced by spinal and shoulder flexibility as well as stretch tolerance [39]. Since there's no statically significant difference between both INJ and N-INJ groups, the lower scores might indicate a limitation for the execution of the techniques in different manoeuvres, therefore needing some improvement, as a higher exposure to injury occurs for all athletes.

The *YBT* was performed due to assess its relation with dynamic balance control and injury prediction. The normalized results obtained for our athletes (anterior=82.1±7.4%; post-medial=127.7±7.8%; post-lateral=122.1±7.6.4%), didn't revealed any statistical significant differences between INJ and N-INJ athletes, and were similar to those obtained by Cruz & Moreira[40] for n=37 Portuguese junior elite surfers (anterior=76.1±7.2%; post-medial=128.7±10.0%; post-lateral=128.8±12.6%). The difference between the right and left reach distance in the anterior direction (YBT anterior asymmetry), although not statistically significant different between both groups (N-INJ=4.0±3.88cm; INJ=4.94±3.27cm) was, on average, ≥ 4cm, which could be associated with up to 2.5 times higher risk of lower extremity injury [31]. As to composite reach distance, even the lowest scores obtained (INJ=109.01±6.12% vs N-INJ=111.01±6.43%) were above the cutting value (94%) associated with poor neuromuscular control and increased risk of lower-extremity injury [25,31].

Sport specialization (year-round intensive training in only one specific sports activity) appears to be associated to higher rate of injuries[41,42,43], despite the sex, age and weekly training load[44]. On the one hand, high levels of training for a single sport in adolescence do not improve overall achievement[41]; on the other hand, being exposed to other stimulus resulting from different sports, may decreases the chances of injuries, stress, and burnout in young athletes[45] and even contribute to injury prevention[32,46].

For our sample, being the majority of the injuries sustained located at lower extremities (62.5%), it seems that besides the improvement of the physical fitness, LTAD training programmes must be optimized to prevent them.

As to limitations of this study, we must consider the part of data collection based on a questionnaire, relying on the memory of the participants, and the fact that some of the reported injuries were not evaluated by a health professional, eventually making the injury classification more questionable. Although our sample represents the entire population of elite junior Portuguese surfers who represent the National Surfing Team, we still need a more prospective/ longitudinal study in order establish more solid cause-effect correlations, and to eventually extrapolate our findings to all junior competitor surfers.

V. Conclusion

Musculoskeletal injuries are not frequent in junior elite Portuguese surfers (IP=0.25), being the lower limbs the area where they occur more often (62.5%), with a high time-loss among INJ surfers (> 30 days), while performing manoeuvres performance, in small waves (0.5 to 1m) during training sessions. The results of physical fitness tests were similar for INJ and N-INJ surfers. Although not statistically significant, they show some tendency to lower limbs injury risk, that needs to be cleared with longitudinal studies and bigger samples: maximum ankle dorsiflexion and flexibility of hamstrings and lower back is low, according to the reference values; and coordination, dynamic balance and postural control is also compromised, since YBT anterior asymmetry is above or equal to 4cm.

Follow-up and longitudinal studies are also needed to identify adequate training loads and specific injury prevention strategies for junior surfing populations, mainly directed to the lower limbs. LTAD programmes should be considered and include dry-land training like jumping and/ or landing tasks, in order to protect musculoskeletal and maintain performance while surfing.

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