Research Article/Araştırma Makalesi

Spor Hekimliği Dergisi, 55(2):122-130;2020
Turkish Journal of Sports Medicine
DOI: 10.5152/tjsm.2020.168

Analysis of Joint Range of Motion, Balance and Injury among Kitesurfers: a Cross-Sectional Study

Uçurtma Sörfçülerinde Eklem Açıklığı, Balans ve Yaralanma Analizi: Kesitsel Bir Çalışma

Raziye Dut[1], Gürhan Dönmez[2], Mehmet Kaymakoğlu[3], Mehmet Ali Talmaç[4], Anıl Işık[5], Bulent Bayraktar[6]

[1]*Child Health and Diseases Section, Istanbul Training and Research Hospital, University of Health Sciences, Istanbul, Turkey*
[2]*Department of Sports Medicine, Faculty of Medicine, Hacettepe University, Ankara, Turkey*
[3]*Department of Orthopaedics and Traumatology, Faculty of Medicine, Hacettepe University, Ankara, Turkey*
[4]*Orthopaedics and Traumatology Section, Şişli Etfal Hamidiye Training and Research Hospital, Istanbul, Turkey*
[5]*Sports Medicine Unit, Acıbadem Sports Excellence, Istanbul, Turkey*
[6]*Department of Sports Medicine, Faculty of Medicine, Istanbul University, Istanbul, Turkey*

R. Dut
0000-0002-3202-6614
G. Dönmez
0000-0001-6379-669X
M. Kaymakoğlu
0000-0002-3548-5672
M. A. Talmaç
0000-0001-7734-6438
A. Işık
0000-0003-0663-0276
B. Bayraktar
0000-0001-8102-4896

Geliş Tarihi/Date Received:
21.07.2019
Kabul Tarihi/Date Accepted:
06.10.2019
Yayın Tarihi/Published Online:
29.03.2020

Yazışma Adresi / Corresponding Author:
Raziye Dut
Sağlık Bilimleri Üniversitesi, İstanbul Eğitim Ve Araştırma Hastanesi, Çocuk Sağlığı Ve Hastalıkları, İstanbul, Turkey
E-mail:
raziyemektup@yahoo.com

ABSTRACT

Objectives: In kitesurfing, regular training programs are difficult to implement and also injury risk is high. In this study; shoulder, hip and ankle range of motion (ROM) and balance test results of kitesurfers were compared with healthy controls and the relationships between kitesurfer injuries, and ROM and balance test results were examined.

Material and Methods: For a total of 54 kitesurfers (aged 29.2±11.2 yrs) and 46 controls (aged 29.5±6.8 yrs), shoulder and hip internal (IR) and external rotations (ER), total rotation ability (IR+ER), ankle plantar flexion (PF) and dorsiflexion (DF), and the Y-balance test (YBT) were bilaterally measured and compared. The number, type and area of injuries of athletes after starting kitesurfing were noted.

Results: Bilateral shoulder IR-ER and right hip ER ROM were lower ($p<0.001$), whereas bilateral ankle PF was higher ($p=0.013$) in kitesurfers compared to the control group. YBT measurements were higher in all three directions in kitesurfers ($p<0.001$). At least one sports injury was reported in 55.6% of the kitesurfers. 50.0% of the athletes had experienced injuries requiring physical therapy and rehabilitation. 48.3% had only lower extremity, 20.7% upper extremity and 6.9% vertebral injuries, whereas 20.7% had both lower and upper extremity injuries.

Conclusions: The restriction of shoulder and hip ROM were thought to be depended on the intensive use of the shoulder, and hip stabilizers. The results of this study indicate the necessity of detecting high-risk groups by clinical and kinesiological examinations in kite surfers.

Keywords: Range of motion, balance test, sports injury, kitesurfing

ÖZ

Amaç: Uçurtma sörfünde düzenli antrenman yapmak zor, yaralanma riski ise yüksektir. Bu çalışmada; uçurtma sörfçülerinde omuz, kalça, ayak bileği eklem hareket açıklığı ve denge testi sonuçları sağlıklı kontrol grubu ile karşılaştırıldı ve yaralanmalar ile eklem hareket açıklığı ve denge test sonuçları arasındaki ilişki incelendi.

Gereç ve Yöntem: Toplam 54 uçurtma sörfçüsünün (29.2 ± 11.2 yaşında) ve 46 sağlıklı, düzenli spor yapmayan kontrol bireyinin (29.5 ± 6.8 yaşında); omuz ve kalça iç-dış rotasyonları, toplam rotasyon kapasiteleri, ayak bileği plantar fleksiyon ve dorsifleksiyonları, Y-denge testi değerleri bilateral ölçüldü ve karşılaştırıldı. Sporcularda uçurtma sörfüne başladıktan sonraki yaralanmaların sayısı, tipi ve bölgesi not edildi.

Bulgular: Sporcularda bilateral omuz iç ve dış, sağ kalça dış rotasyonları kontrol grubundan düşük (p<0.001); ayak bileği plantar fleksiyonları yüksek (p<0.05) bulundu. Denge testi ölçüm sonuçları üç yönde de sporcularda daha yüksek bulundu (p<0.001). En az bir yaralanma öyküsü olan uçurtma sörfçüsü oranı %55.6 idi. Sporcuların %50'si fiziksel tedavi ve rehabilitasyon gerektiren yaralanma geçirdiklerini, %48.3'ü alt ekstremite, %20.7'si üst ektremite ve %6.9'u omurga bölgesi yaralanması geçirdiklerini ifade etmişlerdir.

Sonuç: Omuz ve kalça eklem hareket açıklığının sporcularda kısıtlanmış olmasının bu eklemlerdeki aktif stabilizatör kasların yoğun kullanımına bağlı geliştiği düşünülmektedir. Bu çalışmanın sonuçları uçurtma sörfü sporcularında yüksek riskli grupların klinik ve kinezyolojik değerlendirmelerle belirlenmesi gerektiğini göstermektedir.

Anahtar sözcükler: Eklem hareket açıklığı, denge testi, spor yaralanması, uçurtma sörfü

Available at: http://journalofsportsmedicine.org and http://dx.doi.org/10.5152/tjsm.2020.168

Cite this article as: Dut R, Donmez G, Kaymakoglu M, Talmac MA, Isik A, Bayraktar B. Analysis of joint range of motion, balance and Injury among kitesurfers: A cross-sectional study. *Turk J Sports Med*. 2020;55(2):122-30.

INTRODUCTION

Kitesurfing, an extreme sport, which is defined as "A type of sport different from the traditional ones, which has unusual rules and techniques, where the individuals take risks and danger" has gained popularity very quickly (1). Kitesurfing combines aspects of surfing, windsurfing, wake surfing, snowboarding, paragliding, skateboarding, and sailing, and is considered to be a moderate or rigorous type of physical activity that can be done at almost any age (2). The International Sailing Federation (ISAF) and the International Kiteboarding Association (IKA) reported around 1.5 million people kitesurfing all over the world in 2012, and this number continues to increase every year (3). Kitesurfing has five different disciplines including crossing, free-ride, freestyle, speed racing, and wave riding. Crossing requires semi-isometric contraction movements, where abdominal and leg muscles remain under stress during hyperextension of the spine. Freestyle and splash are also characterized by increased hip flexion and hip and knee joint extension before landing. Knees and feet act as shock absorbers in landing. However, shoulders and wrists are the sites where the pain is felt most frequently (4).

Kitesurfers travel over the water surface with a kite (5-20 m^2) connected to a harness on their waist with a 20-25m-long line and a board (120-200 cm) with footpads. Various maneuvers can be performed in the air by vertically lifting the kite and performing jumps up to 15m high and 30m long. The kitesurfer moves on the water surface by leaning back to the water surface according to the "upwind" or "downwind" position of the breeze, performing small flexion movements in the hip and knee and rotating the upper body. Scientific studies about this extreme sport, which imposes severe stress and strain on the musculoskeletal and cardiovascular systems, risk of injury, permanent damage and even death are limited (4-7). Since treatment of these injuries is difficult, time-consuming and expensive, it is essential to determine the possible biomechanical imbalances for injury prevention.

In kitesurfing, regular training programs are difficult to implement and preventive exercise programs are not available yet. To determine injury risk, it is essential to understand the association between range of motion (ROM) and the injury. ROM is determined by a number of anatomical, biomechanical and physiological factors (8). For this purpose, kitesurfers' shoulder, hip and ankle ROMs, and balance test results were compared with healthy sedentary controls, and relationships with injuries were assessed.

MATERIAL AND METHODS

The study was carried out on sedentary healthy subjects (control group) and kitesurfers (study group) who had participated in the Maximum Kiteboard Turkey Open and the European Kitesurfing Competitions held in Istanbul in August 2017. Ethical approval was taken from the İstanbul University Faculty of Medicine (Approval date: 11.08.2016, number: 2016-13/16). A voluntary consent form was signed by all participants. Out of 200 kitesurfers, 54 Turkish kitesurfers volunteered. The control group consisted of 46 healthy volunteers who did not have any known disease and were not under medical follow-up.

Questions about "year and age of starting kitesurfing", "training status", "history of injury (water/beach, training/competition, off-shore/on-shore)", "injury site", "contacting a physician", and "physical therapy and rehabilitation requirements" were answered by the kitesurfers. Shoulder and hip internal- (IR) and external-rotation (ER), total rotation ability (IR+ER), joint range of motion (ROM), ankle plantar flexion (PF) and dorsiflexion (DF) were evaluated with a standard conventional goniometer. Dynamic muscle balance was measured by Y-balance test (YBT). Participants with an active injury, using medications, or receiving physical therapy were excluded from the study. All analyses were performed minimum 12 h after training or competition without any alcohol consumption for at least 24 h. Male athletes were wearing sea-shorts, while female athletes had swimsuits or bikinis. Measurements were performed by the same physiotherapist in the beach facilities where the competition was held.

IR-ER was bilaterally measured in the active ROM within the range of 0-180°. Excellent reliability was reported for the manual goniometer as a measuring instrument for the upper and lower limbs joints (9). The YBT Kit (Perform Better, West Warwick, Rhode Island, USA) was used to evaluate dynamic muscle balance. It is consisted of three connected cylindrical tubular plastic bars marked in 0.5 cm increments. Each bar has a moveable indicator plate, which the subject moves by pushing with the toes, without bearing weight on the indicator. Three measurements were made for each lower extremity in each anterior, posteromedial and posterolateral direction and the most precise two results were recorded.

Statistical Analysis

Statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS, v15.0, IBM, Armonk, NY, USA). Descriptive statistics of the numerical data were reported as means, standard deviations (SD), minimum and maximum figures, while categorical data were represented as frequency (n) and percentage. For two independent groups, the Mann-Whitney U- and Student's t-tests were used. The Chi-Square test was performed to compare categorical data. The relationships between numerical variables were examined through the Spearman correlation analysis. The level of significance was set at <0.05.

RESULTS

A study group of 45 males and nine females, and a control group consisting of 37 males, and nine females were analyzed. The physical features of all participants are given in Table 1.

Mean age of joining sports in the study group was 15.4±9.0 years, while the mean kitesurfing starting age was 23.1±10.1 years. There was no difference in starting ages regarding gender (p=0.061 and p=0.990). In the study group, a positive correlation was detected between the length of the board used in kitesurfing and age (rho=0.376, p=0.008), height (rho=0.388, p=0.007), body weight (rho=0.523, p<0.001), and body mass index (rho=0.429, p=0.005). Mean measurements of both shoulders' IR-ER and right hip ER were lower in the study group, whereas those for both ankles' PF were higher than the controls' (Table 2).

Table 1. Physical features of the participants

Parameter	Study group (N=54)	Control group (N=46)	*P*
Age (yr)	29.9±11.3	30.1±6.9	0.887
Height (cm)	174.6±8.0	174.6±8.1	0.997
Weight (kg)	71.8±13.5	73.5±12.4	0.527
BMI (kg/m^2)	23.4±3.1	24.0±2.9	0.320
Female gender	9; 16.7	9; 19.6	0.707
Energy drink usage	19; 35.2	7; 15.2	***0.023***
Regular physical activity	48; 90.6	5; 10.9	***<0.001***

Data as mean±SD or n; %

Table 2. Mean ROM and YBT scores of both groups

Test	Direction	Study group	Control group	P
Shoulder ROM	Right IR	71.1±16.5	80.8±7.3	***<0.001***
	Right ER	80.8±18.7	90.6±7.0	***<0.001***
	Left IR	72.0±16.3	81.8±6.1	***0.007***
	Left ER	80.6±15.1	89.2±6.5	***0.001***
Ankle ROM	Right PF	50.6±8.9	43.4±8.9	***<0.001***
	Right DF	20.3±6.9	21.6±2.9	0.099
	Left PF	50.0±8.3	43.6±9.0	***<0.001***
	Left DF	21.1±6.7	22.1±2.8	0.280
Hip ROM	Right IR	35.7±9.2	37.3±4.9	0.139
	Right ER	34.9±8.1	37.8±4.2	***0.013***
	Left IR	36.3±8.8	37.9±5.9	0.293
	Left ER	36.1±7.9	37.6±3.9	0.120
YBT(cm)	Anterior-R	64.5±8.7	56.2±5.6	***<0.001***
	Postmed-R	102.2±8.5	91.3±7.9	***<0.001***
	Postlat-R	106.9±9.5	88.8±9.4	***<0.001***
	Anterior-L	64.1±9.6	57.6±9.1	***<0.001***
	Postmed-L	105.9±17.2	94.1±16.2	***<0.001***
	Postlat-L	106.9±10.5	89.4±8.5	***<0.001***

Figures as mean±SD; ROM: range of motion in °, IR: internal rotation, ER: external rotation, PF: plantar flexion, DF: dorsiflexion; R: right, L: left; YBT: Y-balance test; Postmed: posteromedial, Postlat: posterolateral

At least one sports injury was reported in 30 (55.6%) of the kitesurfers. No relationship was found between sex and injury (p=0.142). Of the athletes, 21 (70.0%) had a single site injury, seven (23.3%) had two injuries, and two (6.7%) had three injuries. About 28 (93.3%) athletes reported receiving medical support after injury. Additionally; of the injuries, 36.7% (n=11) were reported to require hospitalization, and 50.0% (n=15) needed physical therapy and rehabilitation. Twenty-three (76.7%) athletes mentioned that they underwent advanced MRI or CT scans.

When injury sites were examined, 48.3% (n=14) had only lower extremity injuries, 20.7% (n=6) had only upper extremity injuries, 6.9% (n=2) had only vertebral injuries, and 20.7% (n=6) had both lower and upper extremity injuries.

Arm (20.7%, n=6) and shoulder (10.4%, n=3) injuries were most common among upper extremity injuries, while knee (37.9%, n=11) and ankle (20.7%, n=6) injuries were the most common lower extremity injuries. Muscle/tendon (57.7%, n=15) and bone injuries (34.6%, n=9) accounted for the most common injury types. The mean duration of training and the rate of regular physical activity were higher in athletes with previous injury history than in those without such a history (p=0.036 and p=0.048). Injury status and joint ROM measurements are shown in Table 3.

Relationships between joint ROM and YBT in those with multiple injuries are shown in Table 4. Left shoulder IR was lower in athletes with upper extremity injury than in those without an injury history (64.8±17.0 vs. 78.1±15.8, p=0.038). There was no difference in injury frequency concerning the dominant site (in both upper- and in lower-extremity injuries) (p=0.580 and p=0.928). In athletes with a history of lower extremity injury, hip IR/ER was not different from those without any injury history (p>0.05), and only anterior-left measurements were lower in the YBT (61.5±7.6 vs. 68.1±6.2, p=0.031).

Table 3. Comparison of ROM and YBT of study group participants with/without history of injury

Tes	Direction	No Injury		History of Injury		p
Shoulder ROM	Right IR	77.4±11.4	(45-110)	72.8±17.0	(29-106)	0.230
	Right ER	86.8±14.0	(40-110)	82.4±17.6	(49-125)	0.266
	Right IR+ER	164.1±14.3	(120-194)	155.2±23.8	(78-195)	***0.049***
	Left IR	78.1±11.1	(43-92)	73.5±16.9	(28-98)	0.376
	Left ER	86.5±10.4	(45-102)	81.0±15.5	(37-115)	0.075
	Left IR+ER	164.6±14.1	(126-185)	154.5±25.2	(75-190)	0.083
Hip ROM	Right IR	37.0±5.5	(24-52)	36.1±9.9	(16-62)	0.566
	Right ER	36.8±6.2	(24-55)	35.1±7.6	(14-45)	0.538
	Right IR+ER	73.7±8.9	(55-106)	71.2±13.1	(45-107)	0.202
	Left IR	37.3±6.1	(20-51)	36.9±9.8	(19-70)	0.826
	Left ER	37.0±5.1	(26-50)	36.1±7.9	(21-61)	0.479
	Left IR+ER	74.2±8.7	(55-91)	73.0±15.5	(44-131)	0.614
Ankle ROM	Right DF	21.3±4.7	(8-35)	20.2±6.6	(9-35)	0.312
	Right PF	40.1±1.3	(30-70)	48.1±8.6	(34-68)	0.524
	Left DF	21.9±4.8	(10-38)	20.8±5.9	(11-39)	0.360
	Left PF	46.4±10.1	(30-75)	48.2±7.2	(35-60)	0.206
YBT (cm)	Anterior-R	60.1±7.7	(42-86)	61.4±9.2	(45-81)	0.473
	Postmed-R	95.1±9.1	(71-116)	100.8±10.1	(80-120)	***0.005***
	Postlat-R	96.3±12.9	(75-127)	102.9±12.2	(73-128)	***0.011***
	Anterior-L	60.0±9.9	(45-93)	62.9±9.6	(47-94)	0.073
	Postmed-L	99.1±20.9	(75-205)	102.9±10.9	(82-130)	***0.008***
	Postlat-L	96.2±12.0	(74-130)	103.7±13.0	(83-136)	***0.005***

Figures as mean±SD and (min-max); ROM: range of motion in °, IR: internal rotation, ER: external rotation, DF: dorsiflexion, PF: plantar flexion; YBT: Y-balance test; R: right, L: left; Postmed: posteromedial, Postlat: posterolateral

Table 4. ROM correlations with YBT in participants with multiple injuries

Injury	Anterior-R		Postmed-R		Postlat-R		Anterior-L		Postmed-L		Postlat-L	
Measure	**rho**	**p**	**Rho**	**p**	**rho**	**p**	**rho**	**p**	**rho**	**P**	**rho**	**p**
Shoul ROM												
Right IR	0.455	0.305	0.750	0.052	0.714	0.071	0.414	0.355	0.714	0.071	0.523	0.229
Right ER	0.352	0.439	-0.309	0.500	-0.200	0.667	0.404	0.369	-0.200	0.667	-0.404	0.369
Right IR+ER	0.727	0.064	0.250	0.589	0.393	0.383	0.649	0.115	0.393	0.383	0.162	0.728
Left IR	0.468	0.290	0.450	0.310	0.523	0.229	0.455	0.306	0.523	0.229	0.436	0.328
Left ER	0.455	0.305	-0.107	0.819	-0.036	0.939	0.468	0.289	-0.036	0.939	-0.126	0.788
Left IR+ER	0.800	***0.031***	0.286	0.535	0.393	0.383	0.847	***0.016***	0.393	0.383	0.162	0.728
Hip ROM												
Right IR	0.255	0.582	0.286	0.535	0.321	0.482	-0.162	0.728	0.321	0.482	0.414	0.355
Right ER	0.679	0.094	0.595	0.159	0.631	0.129	0.873	***0.010***	0.631	0.129	0.409	0.362
Right IR+ER	0.954	***0.001***	0.721	0.068	0.847	***0.016***	0.718	0.069	0.847	***0.01***	0.764	***0.046***
Left IR	0.510	0.243	0.630	0.129	0.704	0.077	0.337	0.460	0.704	0.077	0.860	***0.013***
Left ER	0.691	0.086	0.643	0.119	0.786	***0.036***	0.613	0.144	0.786	***0.03***	0.793	***0.033***
Left IR+ER	0.673	0.098	0.714	0.071	0.821	***0.023***	0.559	0.192	0.821	***0.02***	0.901	***0.006***
Ankle ROM												
Right PF	-0.294	0.572	-0.232	0.658	-0.232	0.658	-0.232	0.658	-0.232	0.658	-0.015	0.978
Right DF	-0.431	0.334	-0.054	0.908	-0.234	0.613	0.073	0.877	-0.234	0.613	-0.327	0.474
Left PF	0.377	0.461	0.371	0.468	0.371	0.468	0.429	0.397	0.371	0.468	0.232	0.658
Left DF	-0.174	0.709	0.072	0.878	-0.108	0.818	0.345	0.448	-0.108	0.818	-0.227	0.624

R: right, L: left; Postmed: posteromedial, Postlat: posterolateral; Shoul: shoulder, ROM: range of motion, YBT: Y-balance test; IR: internal rotation, ER: external rotation, PF: plantar flexion, DF: dorsiflexion

DISCUSSION

Kitesurfing injuries are mainly acute (5). Overall injury rate was reported to be 5.9-7.0 injuries per 1000 kitesurfing hours in non-competitive kitesurfing, while this rate was 12 injuries per 1000 kitesurfing hours in competitive kitesurfing (10,11). The ankle (64%), foot (14%), knee (11%) and leg (11%) have been reported as the most commonly injured lower extremity sites (6). Upper extremities (18-22%) were the second most common site of injuries, followed by trunk (4-15%) and head (2-14%) injuries. Studies reported that the most common injury types were joint sprains (40%) followed by contusions (34%), abrasions (28%), and muscle or tendon damage (18%) (12,13). In this study, the frequency of lower extremity injuries was 48.3%, and both upper and lower extremity injuries were 20.7% in kitesurfers such as past reports. Lower extremity injury tend to be common because they all held weight and support balance. And arm injury was the most common site among upper extremity injuries while knee injury was the most common among lower extremity injuries because of that kitesurfing sports needed to use mostly arm joints softly and leg especially knee and ankle for turning on waves and keeping balance. Muscle/tendon injuries were accounted for the most common injury types. We thought that knee injury and hip health could be mentioned together.

In the literature, prospective (14) and retrospective (15) studies as well reported that hip muscle weakness is associated with knee injury (16). However, in this study, only the right hip ER in the lower extremity was significantly lower than in controls. Hip-abductor and external-rotator restriction leads to injury by altering trunk or lower extremity kinematics, resulting in increased mechanical stresses on joints and soft tissues (17). Hip-abductor and external-rotator weakness diminish the control of dynamic knee valgus by causing excessive femoral internal rotation and adduction (17-19). This may result in recurrent stress injuries such as patellofemoral pain and iliotibial band syndrome, or traumatic injuries such as a non-contact ACL rupture.

The low levels of mean upper extremity shoulder joint IR and ER ROMs may be due to the use of shoulder stabilizers to control the handlebar of the kite that they hold, which may lead to injury. The shoulder joint mechanism controls the position of the hand in front of the trunk and also controls the elbow joint to allow the motor function to be performed (20). Shoulder joint ROM, and IR/ER muscle strength are essential factors in performance, overuse injury rate and rehabilitation (21). In the shoulder joint with movement restriction, it was reported that the most recently acquired movement after standard physical therapy was IR, and most significant losses of both active and passive ROMs were in ER (22).

However, reduced hip ROM may lead to microtrauma, joint contractures, and structural changes due to impaired kinematics of the hip and pelvis with an adaptation similar to IR restriction in the glenohumeral joint (23). In this study, we thought that the difference between the upper- and the lower extremities may be due to the intensive use of a right hip stabilizer to achieve balance on the surfboard, and protection from traumas by providing balance control on the right foot.

The YBT is a functional test that requires strength, flexibility, neuromuscular control, ROM, balance, and proprioception (24). The anterior, posteromedial and posterolateral directions have the most predictive ability for an increased injury risk (13). It was found that this test was predictive for lower extremity injuries in basketball players, and revealed chronic knee instability (25-27). Gribble et al. established that with a difference of more than 4 cm in anterior reach between the lower extremities, the individual is at a 2.5-times increased risk for a non-contact injury (9).

The high level of YBT measurements in the study group showed that their balance is quite high; therefore, kitesurfing has an advantage in this respect. However, bilateral posteromedial and posterolateral measurements were detected to be higher in athletes with an injury history than those without one. Additionally, there was no difference between the two groups in bilateral anterior balance measurements. Performance on dynamic balance depends on an individual's age, gender, sport, competition level, and motor development components (28).

YBT studies in the literature have been conducted about the mechanism, technique, and kinetics in sports such as basketball, football, volleyball, tennis, and swimming (26-30). YBT results obtained in competitive kitesurfers in this study may be the first ones performed in this sport. Therefore, according to technical and mechanical properties of kitesurfing, dynamic balance measurements may be different from other sports branches. We believe that this result will be a good reference for further balance studies in kitesurfing. At the same time, the results of this study suggest that YBT may be an inadequate measurement tool for lower extremity injury in kitesurfers, and internal/external factors that may affect the damage should be examined. Most common risk factors are bilateral strength imbalances, strength deficits, low agonist/antagonist ratios, muscle fatigue, insufficient warm-up, anatomical and morphological muscle features, poor lumbar posture, and core stability disorders (31).

YBT may help identify flexibility deficits and flexibility asymmetries in the ankle and hip regions (32). A correlation between hip IR/ER and YBT was detected in the present study. In the balance test of kitesurfers with multiple injury history, both hips IR+ER total ROM had positive correlations with PostlatR, PostmedL, PostlatL; and the right hip had an additional one with anteriorR. The relationship between hip strength and the YBT has not been fully elucidated. However, a weak correlation was detected between YBT and hip ER and IR forces (33). The results suggest that kinetics vary in kitesurfers and relationships should be assessed.

On the other hand, it was reported for competitive kitesurfers that bilateral ankle PF was higher than the controls, and that right ankle DF was lower than that of the left ankle. Data obtained from the measurements of PF and DF may be useful to determine the risk of anterior cruciate ligament injury in kitesurfers. Ankles with greater PF strength and smaller DF/PF ratio also had higher incidence of inversion ankle sprains (34). Besides, a restricted DF is associated with greater knee-valgus displacement during landing, because large ground reaction forces, valgus displacement, and limited knee-flexion displacement during landing are ACL injury risk factors (35).

We suggest that exercise programs and training plans recommended for kitesurfing should be extraordinary. Kitesurfing is a kind of sport that includes many components such as force, coordination, agility, and durability. Training should be targeted on practiced discipline, and a medium to high level of aerobic fitness is vital in course racing. In freestyle competitions, training should focus on exercises for proprioception, core stability, and articular mobilization to prevent possible injuries (5,13,36).

There are some limitations to our study. First, no question was asked to the participants about where the injuries took place. According to literature, 54% of the injuries occur in water at a distance >50 m to the beach, 26% occur at a distance of <50 m to the beach, and 20% occur on the beach (13). Additionally, no question was either asked to the participants about injury occurrence on-shore/off-shore (37). Second, injury frequency per 1000 training hours was not be evaluated in the study group. Most of the time, athletes can spend time waiting for wind on the beach. This situation complicates the planning of studies and makes it difficult to obtain injury data per 1000 training hours. In this study, injuries that occurred any time after onset of kitesurfing were examined, regardless of how they occurred.

To conclude, to the best of our knowledge, this is the first documented study that examines the relationships between shoulder/hip/ankle ROM, YBT measurements and injuries in kitesurfers. Results support the necessity of regular check-ups to identify high-risk muscle injuries in kitesurfers. Kitesurfers should be assessed using clinical and kinesiological examinations. We hope that the results of this study will guide research in determining possible injury mechanisms, and creating injury prevention strategies in kitesurfers.

REFERENCES

1. Berneira JdO, Domingues MR, Medeiros MAd. Incidence and characteristics of kitesurfer injuries. *Braz J Kinanthropom Hum Perform*. 2011;13(3):195-201.
2. Essome E. Meet David: the 77 year old kite surfer showing the rest of us how it's done. https://mpora.com/windsurfing-kitesurfing/77-year-old-surf-1#FjW0xV6RR6WOWsTg.97; 2015.
3. International Sailing Federation. *ISAF Kiteboarding Format Trials. Technical Report*. Santander; 2012. https://saveolympicwindsurfing.files.wordpress.com/2012/06/analysis-of-technical-report1.pdf.
4. Lundgren LE, Brorsson S, Hilliges M, et al. Sport performance and perceived musculoskeletal stress, pain and discomfort in kitesurfing. *Int J Perform Anal Sport*. 2011;11(1):142-58.
5. Bourgois JG, Boone J, Callewaert M, et al. Biomechanical and physiological demands of kitesurfing and epidemiology of injury among kitesurfers. *Sports Med*. 2014;44(1):55-66.
6. Pérez-Turpin JC, Cortell-Tormo JM, Suárez-Llorca C, et al. Injuries in elite male kitesurfers. *Retos. Nuevas Tendencias en Educación Fisica, Deportes y Recreación*. 2011;20(2):30-2.
7. Vercruyssen F, Blin N, L'Huillier D, et al. Assessment of physiological demand in kitesurfing. *Eur J Appl Physiol*. 2009;105(1):103-9.
8. Baechle TR, Earle RW. *Essentials of Strength Training and Conditioning.* Champaign, IL: Human Kinetics, 3rd ed; 2008.
9. De Carvalho RM, Mazzer N, Barbieri CH. Analysis of the reliability and reproducibility of goniometry compared to hand photogrammetry. *Acta Ortop Bras*. 2012;20(3):139-49.
10. Petersen W, Hansen U, Zernial O, et al. Mechanisms and prevention of kitesurfing injuries. *Sportverletz Sportschaden*. 2002;16(3):115-21.
11. Wegner M, Wegener F. The relationship between sensation seeking and tendency to suffer injuries among kite surfers. *Zeitschrift für Sportpsychologie*. 2012;19(3):122-30.
12. Lundgren L, Brorsson S, Osvalder AL. Injuries related to kitesurfing. *World Acad Sci Eng Technol.* 2011(77):1132-6.
13. Nickel C, Zernial O, Musahl V, et al. A prospective study of kitesurfing injuries. *Am J Sports Med.* 2004;32(4):921-7.
14. Nadler SF, Malanga GA, DePrince M, et al. The relationship between lower extremity injury, low back

pain, and hip muscle strength in male and female collegiate athletes. *Clin J Sport Med*. 2000;10(2):89-97.

15. Niemuth PE, Johnson RJ, Myers MJ, et al. Hip muscle weakness and overuse injuries in recreational runners*. Clin J Sport Med*. 2005;15(1):14-21.
16. Powers CM. The influence of abnormal hip mechanics on knee injury: a biomechanical perspective*. J Orthop Sports Phys Ther*. 2010;40(2):42-51.
17. Cashman GE. The effect of weak hip abductors or external rotators on knee valgus kinematics in healthy subjects: a systematic review*. J Sport Rehabil*. 2012;21(3):273-84.
18. Boling MC, Padua DA, Alexander Creighton R. Concentric and eccentric torque of the hip musculature in individuals with and without patellofemoral pain*. J Athl Train*. 2009;44(1):7-13.
19. Yu B, Garrett WE. Mechanisms of non-contact ACL injuries. *Br J Sports Med*. 2007;41(Suppl 1):i47-51.
20. Jobe CM, Phipatanakul WP, Coen MJ. Gross anatomy of the shoulder. In: CA Rockwood, FA Matsen, Eds. *The Shoulder*, 4th ed. Philadelphia: WB Saunders, Elsevier; pp 33-100; 2009.
21. Ellenbecker TS, Roetert EP, Bailie DS, et al. Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Med Sci Sports Exerc*. 2002;34(12):2052-6.
22. Johnson AJ, Godges JJ, Zimmerman GJ, et al. The effect of anterior versus posterior glide joint mobilization on external rotation range of motion in patients with shoulder adhesive capsulitis. *J Orthop Sports Phys Ther.* 2007:37(3):88-99.
23. MacWilliams BA, Choi T, Perezous MK, et al. Characteristic ground-reaction forces in baseball pitching. *Am J Sports Med*. 1998;26(1):66-71.
24. Gonell AC, Romero JA, Soler LM. Relationship between the y balance test scores and soft tissue injury incidence in a soccer team. *Int J Sports Phys Ther*. 2015;10(7):955-66.
25. Hegedus EJ, McDonough SM, Bleakley C, et al. Clinician-friendly lower extremity physical performance tests in athletes: a systematic review of measurement properties and correlation with injury. Part 2-the tests for the hip, thigh, foot and ankle including the star excursion balance test*. Br J Sports Med*. 2015;49(10):649-56.
26. Hertel J, Braham RA, Hale SA, et al. Simplifying the star excursion balance test: analyses of subjects with and without chronic ankle instability. *J Orthop Sports Phys Ther*. 2006;36(3):131-7.
27. Plisky PJ, Rauh MJ, Kaminski TW, et al. Star Excursion Balance Test as a predictor of lower extremity injury in high school basketball players. *J Orthop Sports Phys Ther*. 2006;36(12):911-9.
28. Butler RJ, Queen RM, Beckman B, et al. Comparison of dynamic balance in adolescent male soccer players from rwanda and the United States. *Int J Sports Phys Ther*. 2013;8(6):749-55.
29. Chimera NJ, Smith CA, Warren M. Injury history, sex, and performance on the functional movement screen and Y balance test. *J Athl Train*. 2015;50(5):475-85.
30. Gribble PA, Hertel J, Plisky P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury: a literature and systematic review. *J Athl Train*. 2012;47(3):339-57.
31. Van Pellicom P, Vanmaele R, Welvaert M. Functional Movement Screen and Y-balance test: validity in hamstring injury risk prediction? A prospective study. *Master of Science, Faculteit Geneeskunde en Gezondheidswetenschappen.* Belgium: *Universiteit Gent*; 2014-2015.
32. Wilson BR, Robertson KE, Burnham JM, et al. The relationship between hip strength and the Y Balance Test. *J Sport Rehab*. 2018;27(5):445-50.
33. Overmoyer GV, Reiser RF 2nd. Relationships between lower-extremity flexibility, asymmetries, and the Y balance test. *J Strength Cond Res*. 2015;29(5):1240-7.
34. Baumhauer JF, Alosa DM, Renström AF, et al. A prospective study of ankle injury risk factors. *Am J Sports Med*. 1995;23(5):564-70.
35. Fong CM, Blackburn JT, Norcross MF, et al. Ankle-dorsiflexion range of motion and landing biomechanics. *J Athl Train*. 2011;46(1):5-10.
36. Feletti F. Kitesports medicine, kitesurfing and snowkiting. In: F Feletti, Ed. *Extreme Sports Medicine*. Springer; 2016.
37. Exadaktylos AK, Sclabas GM, Blake I, et al. The kick with the kite: an analysis of kite surfing related off shore rescue missions in Cape Town, South Africa. *Br J Sports Med*. 2005;39(5):e26.