RELATIONSHIP BETWEEN THIGH SKIN TEMPERATURE, STRENGTH, AEROBIC AND ANAEROBIC EXERCISE CAPACITIES IN SAILING

Nihan ÖZÜNLÜ PEKYAVAŞ[1]*

Özge CINAR MEDENI[2]

Ayşe UZUN[3]

Gül BALTACI[3]

ABSTRACT

The purpose of this study was to investigate the relationship between thigh skin temperature, knee muscle strength, aerobic and anaerobic exercise capacities in sailing. 20 sailing athletes were assessed during pre-seasonal assessment period. Thermal camera imaging was performed to assess the skin temperature at anterior and posterior parts of thigh for both legs. Knee muscle strength was evaluated by using isokinetic dynamometer, which was found to be a reliable device to evaluate isokinetic knee muscle strength. Treadmill VO_2max Test was performed to monitor the development of athlete's aerobic exercise capacity. The Wingate cycle ergometer test was performed to assess the two major components of anaerobic exercise capacity, namely, maximum anaerobic power and relative anaerobic capacity. No significant relationship was found between anaerobic power- capacity and aerobic capacity ($r<0.50$). Knee muscle strength is in relationship with skin temperature, aerobic and maximum anaerobic capacities ($r>0.50$). Also skin temperature was in relationship with aerobic exercise capacity ($r>0.50$) but not in relationship with anaerobic exercise capacity ($r<0.50$). The increase in these parameters should be considered in training programs to increase aerobic and anaerobic exercise capacities. We should always keep in mind that the temperature increases and there is a risk of injury.

Key Words: Thermograph; Muscle Strength; VO_2max; Wingate cycle ergometer

YELKENCILERDE UYLUK DERI SICAKLIĞI, KUVVET, AEROBIK VE ANAEROBIK EGZERSIZ KAPASITELERİ ARASINDAKİ İLİŞKİNİN ARAŞTIRMASI

ÖZ

Bu çalışmanın amacı yelkencilerde uyluk deri sıcaklığı, diz kas gücü, aerobik ve anaerobik egzersiz kapasiteleri arasındaki ilişkiyi araştırmaktır. Sezon öncesi değerlendirme döneminde 20 yelkenli atlet değerlendirildi. Her iki bacak için uyluk ön ve arka kısımlarındaki cilt sıcaklığını değerlendirmek amacıyla termal kamera ile görüntüleme yapıldı. Diz kası kuvveti, izokinetik diz kas kuvvetini değerlendirmek için güvenilir bir cihaz olan izokinetik dinamometre kullanılarak değerlendirildi. Sporcunun aerobik egzersiz kapasitesinin gelişimini izlemek için koşu bandı VO2max Testi yapıldı. Anaerobik egzersiz kapasitesinin iki ana bileşeni olan maksimum anaerobik güç ve göreceli anaerobik kapasiteyi değerlendirmek için Wingate bisiklet ergometresi testi yapıldı. Anaerobik güç-kapasite ile aerobik kapasite arasında anlamlı bir ilişki bulunamadı ($r <0.50$). Diz kas kuvveti, deri sıcaklığı, aerobik ve maksimum anaerobik kapasitelerle ilişkilidir ($r> 0.50$). Ayrıca deri sıcaklığı aerobik egzersiz kapasitesiyle ($r> 0.50$) ilişkilidir, ancak anaerobik egzersiz kapasitesi ile ilişkili değildi ($r <0.50$). Bu parametrelerdeki artış, aerobik ve anaerobik egzersiz kapasitelerini arttırmak için eğitim programlarında dikkate alınmalıdır. Sıcaklığın artışının yaralanma riskini artırabileceğini göz önünde bulundurmalıyız.

Anahtar Kelimeler: Termograf; Kas Kuvveti; VO_2max; Wingate bisiklet ergometresi

[1] Baskent University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Baglica, 06810, Ankara, Turkey
[2] Cankırı Karatekin University, School of Health, Department of Physiotherapy and Rehabilitation, Cankiri, Turkey
[3] Guven Private Hospitals, Physiotherapy and Rehabilitation Center, Kavaklıdere, 06540, Ankara, Turkey
* Corresponding Author: e-mail: nozunlu@baskent.edu.tr

INTRODUCTION

Aerobic and anaerobic exercise capacities play a major role in sailing sports performance. Sailing performance is reported to be related to aerobic endurance, strength, balance, anaerobic tolerance, and resistance of mental fatigue.[3] Cunningham and Hale (2007), investigated the physiological parameters of sailing and reported a data of sailing heart rates of about 168 beats/min, blood lactate concentrations of 4.5 and VO_2 of 32.2 ml/kg.min (VO_2peak of 58%).[10] Sailors have to tolerate fatiguing contractions of the lower-body muscles for prolonged periods and prevent themselves from injury which would be possible with increasing both aerobic and anaerobic exercise capacities.[24]

Muscle strength of lower extremities is closely related with injuries in sailing. Injuries may result from a lack of general fitness, overuse, overtraining, or macrotraumatic accidents. Many actions in sailing place muscles at high risk by performing explosive, powerful moves, often when they are not warmed up. Strong movements in sailing may lead to back and knee problems.[3] Skin temperature changes are also related with injuries in sports.[14,15] An inflammation in subcutaneous and deeper tissues can be reflected as superficial tissue temperature changes of ≥1°C. Modern infrared cameras have been claimed to be more than 10 times more sensitive in detecting temperature changes than the human hand and fingers that can detect a ≥2°C difference in temperature on a patient's skin.[23]

Considering these studies, aerobic and anaerobic exercise capacities are thought to be related with skin temperatures and knee muscle strength, which are all important parameters for injury prevention. As there is a lack of literature about the assessment of skin temperature in sailing and the relationships between these parameters, our aim for this study was to investigate the relationship between thigh skin temperature, knee muscle strength, aerobic and anaerobic exercise capacities in sailing.

METHOD

Research design and Participants

The study protocol was approved by the Turkish Sailing Federation, and all participants provided a written consent at the beginning of the study. 20 sailing athletes were assessed during pre-seasonal assessment period. The sociodemographic and clinical characteristics were evaluated with an assessment form. Nine of the athletes were competing in Laser category, 1 was competing in Finn category, 4 were competing in 470 Men category, 3 were competing in 470 Women category and 3 were competing in RS:X category.

Outcome Measurements

Thermographic Assessment

Thermal camera imaging was performed to assess the skin temperature at anterior and posterior parts of thigh for both legs (Figure 1). Each athlete was thermographically evaluated in the same room (ambient temperature, 21°C) and athletes were left for 10–20 minutes to 'acclimatise' to the thermographic imaging environment. FLIR E5® Thermal Camera (FLIR Systems AB, Sweden) with a resolution of 120 x 90 pixels was used for thermal imaging and the Color Palette iron was chosen for displaying the images. The athlete stand with both lower extremities undressed. The examiner had the measurements taken from 1m away from the athlete. The location of the highest skin temperature and the highest skin temperature in degrees was recorded. It is indicated that Infrared imaging may be a reliable and valid measure of treatment outcomes with clinical utility and sensitivity.[9]

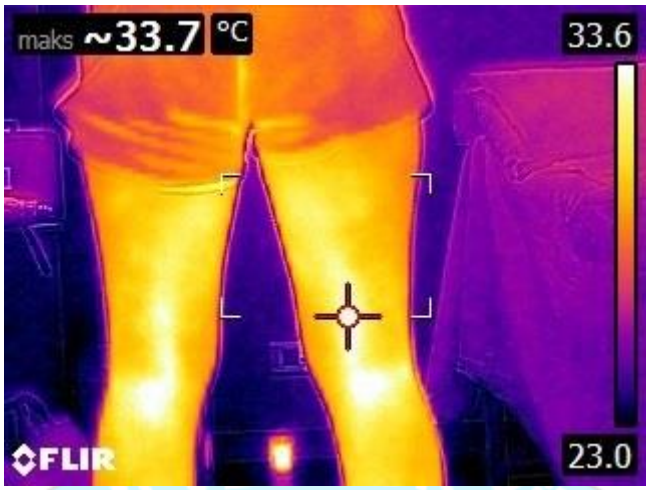

Figure 1. Posterior thermographic assessment of dominant side.

Knee Muscle Strength

Knee muscle strength was evaluated by using ISOMED 2000 (D&R Ferstl GmbH, Hemau, Germany) isokinetic dynamometer, which was found to be a reliable device to evaluate isokinetic knee muscle strength.[11,12] After five-minute warm up on treadmill, the subject seated with the hip and knee flexed 90^{o} and center of the knee joint was aligned with the center of the dynamometer using a laser-pointing device. The subject was asked to push up the lever arm of the dynamometer as strongly as possible and to return to the starting position five times at the angular velocity of 60^{o}/s and then after a 1 minute break; same procedure was repeated at the angular velocity of 120^{o}/s five times. Output data from the assessment were “flexor peak torque” (FPT), “extensor peak torque” (EPT), and “hamstring/quadriceps strength ratio” (H/Q). The data was normalized by dividing strength values to body weight for each subject.

Aerobic Capacity

Treadmill VO_2max Test was performed to monitor the development of the athlete's general endurance (VO_2max).[10] A treadmill where speed and grade of slope can be adjusted and a stop watch was used for evaluation procedure. The athlete ran on the treadmill to exhaustion. At timed stages during the run the slope of the treadmill was increased 2° every minute. The treadmill was set up with a speed of 11.3 km/hr (7.02 miles/hr) and a slope of 0° at the beginning and the athlete commenced the test. At minute intervals during the test the slope of the treadmill was adjusted. From the total running time an estimate of the athlete's VO2max was calculated as follows:

$$VO_2max = 42 + (Time \times 2)$$

"Time" is the total time of the test expressed in minutes and fractions of a minute.[17]

Maximum Anaerobic Power and Maximum Anaerobic Capacity

The Wingate cycle ergometer test [4,5,16,18,19] was performed on a Peak Bike Ergometric 894E (Monark Exercise AB, Vansvro, Sweden) to assess the two major components of anaerobic exercise performance, namely, maximum anaerobic power (Peak- AnP, in Watts) and relative anaerobic capacity (Watt/kg). The Wingate cycle ergometer test is valid in healthy participants [4] and attempts to precisely measure anaerobic power and capacity required for a variety of sporting events. Power refers to maximal (or peak)

power achieved in a 5-second period during the test, whereas capacity refers to the mean power during the entire 30 seconds of the test.

Each test started with a 5 min warm-up on the ergometer at 100 W and 60 rpm with two acceleration phases of 3 s commencing after 90 s and 180 s followed by a 5 min recovery. Time was monitored using a stopwatch and participants were encouraged to pedal as fast as possible for a 30-second period. The cool-down period lasted for 1 to 2 min and consisted of pedaling at low to moderate power level on the ergometer immediately after the test. Verbal encouragement was given to the participants to exert maximum effort.[18,19] Maximum anaerobic power (Peak- AnP), relative anaerobic power per kg (Peak-AnP/kg), mean power (MP) and mean power per kg (MP/kg).[4,5,16,18,19] The mechanical power obtained in the first five seconds of testing time gives the Peak-AnP. MP refers to the mean power produced during the entire test period and gives maximum anaerobic capacity.[16]

Statistical Analysis

Data were analyzed using statistical software (SPSS Version 18, Inc, Chicago, USA). Quantitative analysis of data is reported as mean and standard deviation. Spearman correlation coefficients were calculated to determine the relationships. r-value of ≥ 0.50 and p-value of ≤ 0.05 was accepted as the level of statistical significance for the correlation data.

RESULTS

Sociodemographic characteristics of participants are shown in Table 1.

Table 1. Sociodemographic characteristics of subjects

	Gender	Min.	Max.	X±SD
Age (yrs)	Men (n=14)	17	30	22.28±4.56
	Women (n=6)	19	24	20.66±1.86
BMI(kg/m^2)	Men (n=14)	19	27	23.80±2.50
	Women (n=6)	20	24	22.17±1.37

BMI: Body Mass Index

No significant relationship was found between anaerobic power- capacity and aerobic capacity. Also no significant relationship was found between anaerobic power- capacity and thermographic imaging results. Considering the locations of highest skin temperature by thermal imaging; 75% of Quadriceps muscle, 15% of adductor muscles and 10% of Vastus medialis obliques muscle locations were detected from anterior assessment on dominant side. For non-dominant side; 80% of Quadriceps muscle, 10% of adductor muscles and 10% of Vastus medialis obliques muscle locations were detected from anterior assessment. Considering the locations of highest skin temperature from posterior assessment; 100% of Hamstring muscle location was detected for both dominant and non-dominant sides. Correlations between aerobic capacity, thermographic assessment and knee muscle strength are shown in Table 2. Correlations between anaerobic power-capacity and knee muscle strength are shown in Table 3.

Table 2. Correlations between aerobic capacity, thermographic assessment and knee muscle strength

	Dom 120°/s FPT	NonDom 60°/s FPT	NonDom 120°/s FPT	Dom Ant. °C	Dom Post. °C	NonDom Ant. °C	NonDom Post. °C
VO2max	.565*	.564*	.646*	.621*	.635*		.615*
Dom 60°/s H/Q				.550*	.653*	.545*	.513*
Dom 120°/s FPT	1.00			.540*		.517*	
NonDom 60°/sec FPT		1.00		.547*			.523*
NonDom 120°/s FPT			1.00	.674*	.517*	.519*	.567*

*p<0.05, Dom: Dominant, NonDom: Non-dominant, FPT: Flexor peak torque, EPT: Extensor peak torque, H/Q: Hamstring/quadriceps strength ratio, Ant.: Anterior Assessment, Post.: Posterior Assessment

Table 3. Correlations between anaerobic power-capacity and knee muscle strength

	Dom 60°/s FPT	Dom 60°/s EPT	Dom 120°/s EPT	NonDom 60°/s FPT	NonDom 60°/s EPT	NonDom 120°/s FPT	NonDom 120°/s EPT
MP			.534*				
MP/kg	.619*	.577*	.675*	.519*	.585*	.605*	.631*

*p<0.05, Dom: Dominant, NonDom: Non-dominant, FPT: Flexor peak torque, EPT: Extensor peak torque, H/Q: Hamstring/quadriceps strength ratio

DISCUSSION

We investigated the relationship between thigh skin temperature, knee muscle strength, aerobic and anaerobic exercise capacities in sailing and found that knee muscle strength is in relationship with skin temperature, aerobic and anaerobic exercise capacities. Also skin temperature was in relationship with aerobic exercise capacity but not in relationship with anaerobic exercise capacity.

In many studies, sailors are found to have very high knee flexor and extensor muscle strength than highly strength-trained elite athletes in explosive type sports.[1,7,8,21] Considering the hiking performance (as it requires both aerobic and anaerobic performance), moderate to strong positive correlations have been observed between knee extensor strength and hiking performance.[1,22] Flexor muscles strength of both dominant and non-dominant knee are found in positive relationship with VO_2max and MP/kg results. MP and MP/kg results are also in positive relationship with extensor muscle strength of knee. As MP gives maximum anaerobic capacity, we may consider that as knee muscle strength increases, maximum anaerobic capacity and aerobic capacity increases. It can be stated that increasing the knee strength can prevent possible injuries and by increasing both aerobic and anaerobic exercise capacities in sailing.

Thermography (medical infrared imaging) requires thermal camera and define inflammation as a non-invasive method by viewing the asymmetric heat exchange. Thermography method can display the smallest possible inflammatory signs. Also it is an important equipment to decide the return to play of injured athletes. It displays the skin temperature of the most used muscles as their internal temperature will increase more when used, because of chemical and mechanical exchanges.[2,6,13,20,25] Akimov et al. obtained significant correlations between maximal and mean temperature on sportsmen upper body part and important indexes of aerobic capacity – VO2max and anaerobic threshold.[2] Hildebrandt et al. stated that the temperature above the exercising muscle increased following aerobic exercise (0.7°C) and decreased following anaerobic exercise (-1.5°C).[15] These

studies also support our idea that aerobic and anaerobic exercise capacities might be related with skin temperatures, which are all important parameters for injury prevention.

Considering the limitations of our study, small sample size was the primary limitation and further studies may be carried out with larger number of participants. Another limitation was that the categories of sailing athletes could be more homogenized so the relationships and differences between sailing categories could have been stated.

CONCLUSION

In our study, skin temperatures for anterior/posterior and dominant/non-dominant assessments showed that there was a positive relationship between skin temperature and knee muscle strength. Although significant positive relationship was found between skin temperature and aerobic capacity, no relationship was found with anaerobic capacity. In other words, as knee muscle strength increases, skin temperature increases; and as skin temperature of thigh muscles increase, aerobic capacity increases. Skin temperature increase also means an increase in risk of injury. Although aerobic capacity and knee muscle strength are preventing parameters for injury, we should always keep in mind that the temperature increases and there is a risk of injury.

REFERENCES

1. Aagaard P., Beyer N., Simonsen E.B., Larsson B., Magnusson S.P., Kjaer M.. “Isokinetic muscle strength and hiking performance in elite sailors” Scand J Med Sci Sports. 8(3).pp.138-144,1998.
2. Akimov E.B., Andreev R.S., Arkov V.V., Kirdin A.A., Saryanc V.V., Sonkin V.D., Tonevitsky A.G., “Thermal "portrait" of sportsmen with different aerobic capacity” Acta Kinesiologica. 14(1).pp.7-16,2009.
3. Allen J.B., De Jong M.R., “Sailing and sports medicine: a literature review” Br J Sports Med. 40(7).pp.587-593,2006.
4. Bar-Or O., “The Wingate anaerobic test: An update on methodology, reliability and validity” Sports Med. 4(6).pp.381-394,1987.
5. Beneke R., Pollmann C.H., Bleif I., Leithauser R.M., Hütler M., “How anaerobic is the Wingate anaerobic test for humans?” Eur J Appl Physiol. 87(4-5).pp.388–392,2002.
6. BenEliyahu. D.J., Thermal imaging of sports injuries. Conservative management of sports injuries, Williams&Wilkins, s. 643-657, Baltimore, MD, 1997
7. Bojsen-Møller J., Larsson B., Aagaard P., “Physical requirements in Olympic sailing” Eur J Sport Sci. 15(3).pp.220-227,2015. doi:10.1080/17461391.2014.955130
8. Bojsen-Møller J., Larsson B., Magnusson S.P., Aagaard P., “Yacht type and crew-specific differences in anthropometric, aerobic capacity, and muscle strength parameters among international Olympic class sailors” J Sport Sci. 25(10).pp.1117–1128,2007. doi:10.1080/02640410701287115.
9. Coben R., Padolsky I., “Infrared Imaging and Neurofeedback: Initial Reliability and Validity”. Journal of Neurotherapy: Investigations in Neuromodulation, Neurofeedback and Applied Neuroscience. 11(3).pp.3-13,2008.
10. Cunningham P. Hale T., “Physiological responses of elite Laser sailors to 30 minutes of simulated upwind sailing” J Sports Sci. 25(10).pp.1109-1116,2007.
11. Dirnberger J., Kösters A., Müller E., “Concentric and eccentric isokinetic knee extension: A reproducibility study using the IsoMed 2000-dynamometer” Isokinet Exerc Sci. 20(1).31-35,2012.
12. Dirnberger J., Wiesinger H.P., Stoggl T., Kosters A., Muller E., “Absolute and relative strength-endurance of the knee flexor and extensor muscles: a reliability study using the IsoMed 2000-dynamometer” Sportverletz Sportschaden. 26(3).pp.142-147,2012.
13. Goodman P.H., Heaslet M.W., Pagliano J.W., Rubin B.D., “Stress fracture diagnosis by computer-assisted thermography” Phys Sportsmed. 13(4).pp.114-132,1985.
14. Hildebrandt C., Raschner C., Ammer K., “An overview of recent application of medical infrared thermography in sports medicine in Austria” Sensors. 10(5).pp.4700-4715,2010.
15. Hildebrandt C., Zeilberger K., Ring E.F.J., Raschner C., “The application of medical infrared thermography in sports medicine” Ultrasound. 10(2).pp.257-274,2012.
16. Inbar. O., Bar-Or. O., Skinner. J.S., The Wingate Anaerobic Test, Human Kinetics, s.1-110, Champaign, IL, 1996
17. Mackenzie. B., 101 Performance Evaluation Tests. Electric Word, s.37-38, 2005
18. Maud P.J., Shultz B.B. “Norms for the wingate anaerobic test with comparison to another similar test” Res Q Exerc Sport. 60(2).pp.144-151,1989.
19. Micklewright D., Alkhatib A., Beneke R., “Mechanically versus electro-magnetically braked cycle ergometer: performance and energy cost of the Wingate Anaerobic Test” Eur J Appl Physiol. 96(6).pp.748–751,2006.
20. Sands W.A., McNeal J.R., Stone M.H., “Thermal Imaging and Gymnastics Injuries: A Means of Screening and Injury Identification” Sci Gymnastics J. 3(2).pp.5-12,2011.
21. Shephard R.J., “Biology and medicine of sailing. An update” Sports Med. 23(6).pp.350–356,1997. doi:10.2165/00007256-199723060-00002.
22. Tan B., Aziz A.R., Spurway N.C., Toh C., Mackie H., Xie W., Wong J., Fuss F.K., Teh K.C. “Indicators of maximal hiking performance in Laser sailors” Eur J Appl Physiol. 98(2).169–176,2006. doi:10.1007/s00421-006-0260-3.
23. Vainionpää M.H., Raekallio M.R., Junnila J.J.T., Hielm-Björkman A.K., Snellman M.P.M., Vainio O.M. “A comparison of thermographic imaging, physical examination and modified questionnaire as an instrument to assess painful conditions in cats]” J Feline Med Surg. 15(2).124–131,2012.
24. Vangelakoudi A., Vogiatzis I., Geladas N., “Anaerobic capacity, isometric endurance, and Laser sailing performance” J Sports Sci. 25(10).1095-1100,2007.
25. Walsh. W.M., Helzer-Julin. M. Clinical methods of measuring inflammation. In: Leadbetter. W.B., Buckwalter. J., Gordon. S.L. eds. Sports-induced Inflammation American Academy of Orthopedic Surgeons, s.155-160, Park Ridge, IL, 1990.