ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

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The Effects of Performances in Canoe, Kayak and Rowing on Muscle Oxygen Saturation: Experimental Study

Kano, Kayak ve Kürek Performanslarının Kas Oksijen Doygunluğuna Etkisi: Deneysel Çalışma

Mehmet TOPAL[a], Serdar Orkun PELVAN[b], Savaş AKBAŞ[c]

[a]Department of Recreation, Haliç University Vocational School of Physical Education and Sport, İstanbul, Türkiye
[b]Department of Coaching Education, Marmara University Faculty of Sports Sciences, İstanbul, Türkiye
[c]Department of Physical Education and Sports Education, Marmara University Faculty of Sports Sciences, İstanbul, Türkiye

This study was presented as a summary oral presented in 5th International Zeugma Conference on Scientific Research in January 8-9, 2021, Gaziantep, Türkiye.

ABSTRACT Objective: The aim of this study is to compare the intramuscular oxygen saturation results during the short and long distance performances of canoe, kayak and rowing athletes. **Material and Methods:** 30 male international level and licenced athletes (8 canoeists, 11 kayakers and 11 rowers) are participate to this study; age 20.53±3.23 year, height 181.70±7.90 cm, body weight 78.60±11.22 kg and body mass index 23.73±2.37. The intramuscular oxygen saturation status of athletes were measured using the near infrared spectroscopy technology for 40 second sprint and 4 minutes tests performed on the land with branch-specific ergometers. Data collecting processes were recorded as 5 minute rest, 40 second sprint, 10 minute rest, 4 minute distance performances and 5 minute recovery, in total nearly 25 minute. **Results:** Comparing the intramuscular oxygen saturation values of canoe, kayak and rowing athletes, no significant difference was found in the decrement rate to minimum, during 40 second sprint for biceps brachii and vastus lateralis ($p>0.05$). As we compare to 4 minute performances, a significant difference was found in both muscle groups for all three branches. It was seen that the difference was between rowing and canoe athletes, and lower intramuscular oxygen saturation values were found in canoeists compared to rowers ($p<0.05$). **Conclusion:** The results show that intramuscular oxygen saturation it can be said that many factors effect such as differences between branches, posture position, cardiovascular differences between athletes, using of body parts, and number of stroke per minute.

Keywords: Near infrared spectroscopy; muscle oxygen saturation; dynamic exercise; oxygenation

ÖZET Amaç: Bu çalışmanın amacı, kano, kayak ve kürek sporcularının kısa ve uzun mesafe performansları sırasında kas içi oksijen saturasyon sonuçlarını karşılaştırmaktır. **Gereç ve Yöntemler:** Bu çalışmaya 30 erkek uluslararası düzeyde ve lisanslı sporcu (8 kanocu, 11 kayakçı, 11 kürekçi) katılmıştır; yaş 20,53±3,23 yıl, boy 181,70±7,90 cm, vücut ağırlığı 78,60±11,22 kg ve beden kitle indeksi 23,73±2,37'dir. Sporcuların kas içi oksijen saturasyon durumu, yakın kızılötesi spektroskopi teknolojisi kullanılarak, branşa özel ergometreler ile karada 40 sn sürat ve 4 dk mesafe testleri yapılmıştır. Veri toplama işlemleri 5 dk dinlenme, 40 sn sprint, 10 dk dinlenme, 4 dk mesafe performansları ve 5 dk toparlanma olmak üzere toplamda yaklaşık 25 dk olarak kayıt altına alınmıştır. **Bulgular:** Kano, kayak ve kürek sporcularının biceps brachii ve vastus lateralis kasları kas içi oksijen saturasyon değerleri karşılaştırıldığında, 40 sn'lik sprintte minimuma düşme hızında anlamlı bir fark bulunmamıştır ($p>0,05$). Dört dk'lık performansları karşılaştırdığımızda, her üç dal için her iki kas grubunda da anlamlı bir fark bulunmuştur. Farklılığın kürek ve kano sporcuları arasında olduğu görülmüş, kanocularda kürekçilere göre daha düşük kas içi oksijen saturasyon değerleri bulunmuştur ($p<0,05$). **Sonuç:** Araştırmamızdaki kas içi oksijen saturasyonunun branşlar arasındaki farklılıklarında, duruş pozisyonunu, sporcular arasındaki kardiyovasküler farklılıkların, vücut bölümlerinin kullanımının, dakikadaki kürek sayısı gibi birçok faktörün etkili olduğu söylenebilir.

Anahtar Kelimeler: Yakın kızılötesi spektroskopisi; kas oksijen doygunluğu; dinamik egzersiz; oksijenasyon

Correspondence: Mehmet TOPAL
Department of Recreation, Haliç University Vocational School of Physical Education and Sport, İstanbul, Türkiye
E-mail: mehmettopal@halic.edu.tr

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Since the late 1980s, Near Infrared Spectroscopy (NIRS) has been used to investigate local muscle oxidative metabolism during resting and performing different exercises. One of the key advantages of using NIRS is that its signals can produce acceptable signal-to-noise ratios even during dynamic exercise. Previously, detailed reviews on the NIRS methodology as well as its medical applications and potential limitations have been published. There is also a list of useful practical recommendations to perform muscle NIRS measurements.[1,2] Introduced in the 1990s, NIRS offers the advantage of continuous measurement of regional oxyhemoglobin (O_2Hb) saturation on a scale from 0% to 100%. It is known that tissue oxygen saturation provides information about the balance between oxygen supply and oxygen demand of the muscles, mainly at a superficial level. In addition, regional O_2Hb saturation represents the tissue reserve capacity following tissue oxygen extraction.[3]

To date, many studies have proven the role of NIRS in evaluating sport activities and oxidative skeletal muscle performance in athletes. In the first studies performed with well-trained rowers, the wearable NIRS instrument was used to examine muscle metabolism.[4] The quadriceps oxygen saturation profile was investigated using a single channel during simulated competition (2,000 m) on a rowing ergometer. In another study, the literature has been reviewed for the use of NIRS in sports, including articles on alpine skiing, cross-country running, treadmill running, rowing, weightlifting, cycling, speed skating, sprinting, and arm cycling.[5] Then, the research has been focused on the application of NIRS determining how it can be used to design training programs for athletes in sports science.[6] Recently, studies on the effects of endurance, interval and hypoxic training on muscle oxygen saturation (SmO_2) in untrained and trained individuals were reviewed.[3]

The Olympic singles events of Canoe and Kayak Sprint races are performed as for men 200 m and 500 m (38-120 sec) for women and 200 m and 1,000 m (34-220 sec). Recently, shorter races (200 m) have been added to the Canoe Sprint Olympic program, and for these races, there have been studies investigating the indicators for the main upper body. In a study, the upper body strength of 200 m male athletes and their performance on the 200 m kayak ergometer were examined, and it was found that upper body muscle strength is highly correlated with short-distance performance of the athletes.[7] Other studies found that national level kayakers specializing in 200 m races have been found to have lower maximum oxygen consumption (VO_2max) (4.45 L/min) than those in other studies performed with 500 m and 1,000 m races (4.7 to 4.8 L/min).[8-10]

In rowing, there are three main race categories that should be considered: 2,000 m, 1,000 m and head races. Two km races typically last from 5:30 to 8:00 min with stroke rates ranging from 32 to 42 per minute. Average power per stroke in elite men's eight is between 450 and 550 W but can be as high as 1,200 watt (W). On the other hand, as a result of the research conducted by measuring 6-min ergometer performances of rowing athletes, which is similar to the 4-min distance performances in our study, an average power output of 390±13.6 W for male rowers, and 300±18.4 power output for women for 3 min were observed.[11]

Studies show that muscle O_2 saturation can be an important physiological factor for canoe, kayak and rowing performances. In addition, kayak and canoe athletes mainly use smaller muscle mass (upper body and core muscles) and show lower VO_2max than rowers or cross-country kayak athletes.[12] Therefore, in this study, we aim to investigate the effect of short (40 sec) and long (4 min) distance performances of canoe, kayak and rowing athletes on their intramuscular oxygen saturation levels.

MATERIAL AND METHODS

The study was approved by the Marmara University Faculty of Medicine Clinical Research Ethics Committee (date: September 13, 2019, no: 812). This study was conducted in accordance with the Principles of the Declaration of Helsinki. All participans in the study signed an informed consent form.

PARTICIPANTS

The research group consists of 30 licensed (international level; 8 canoeist, 11 kayakers, 11 rowers) male athletes who participated voluntarily in this study. Participants were 20.5±2.5 age, 78.6±10.2 kg of body weighted, 181.7±6.2 cm of height, 23.7±2.4 body mass index and 6.3±2.5 years of sport age.

TEST PROTOCOLS

Warm-up: All subjects started the tests with the warm-up program that we have determined beforehand. The warm-up program consisted of 15 min of technical exercise, followed by 3x250 m of acceleration, 3x200 m of start, and 5 min of rowing at 70% of the race speed. Afterward, each subject was given a 10 min individual warm-up period, not exceeding 60% of the race pace, in order to complete their individual psychological and physiological warm-up. Each test will take place in the ergometers specific to the branches performed by the subjects. A total warm-up time of 40 min was provided for each subject. After 40 min, 10 min rest period was given to contribute to the recovery of the athletes, and then the test protocol was started.

Tests: Performance protocols were carried out on ergometers specific to each subject's branch (canoe, kayak and rowing ergometers). The tests were applied as two different intensities for each subject: 40 sec of maximum sprint (~200 m) and 4 min of maximum intensity (~1,000 m). Pre-test muscle oxygenation values were taken from all subjects 5 min before the measurement, and 40 sec sprint performance tests were performed immediately after. During the next 10 min, the recovery data of the athletes were collected in the resting position specific for each sport branch, and then the long-distance maximum performance values for 4 min stage were measured. Finally, after 4 min of sprint, the recovery data was collected 5 min, and the test was completed. All athletes were asked to remain still on the ergometer during the rest/recovery periods before and after both sprints. Our performance tests included exercises at two different maximum intensities, 40 sec and 4 min, on a canoe and kayak ergometer (Dansprint, Hvidovre, Denmark) and a rowing ergometer (Concept2, Vermont, USA). Before all tests, the drag factor was standardized according to the athlete by calibrating the relevant ergometer. The data obtained in the ergometer performances of the athletes were monitored by the researcher for data standardization and data loss prevention.

NIRS Measurements: In this study, the intramuscular oxygen saturation status of the athletes in canoe, kayak and rowing were measured with ergometer tests on land, using NIRS technology, and the results between different branches were examined. Intramuscular oxygen saturation measurement was performed using wireless and portable "BSXinsight" brand "running" model NIRS. The devices were fixed to the skin with a dark colored non-adhesive elastic bandage and were covered with a tape to ensure that ambient light did not penetrate. Before bandaging, the skin surface was wiped with a disposable antiseptic wipe for each athlete.

SmO_2 measurements were taken from 2 different muscles and that muscles are involved in the canoe, kayak and rowing stroke cycle: M. vastus lateralis (VL) and M. biceps brachii (BB).

Prior to the protocol, devices were placed dominant leg on the VL, lateral to the M. quadriceps femoris muscle, 15 cm away from the patella, for the kayak and rowing subjects. For the right arms of the same subjects, the device was placed medially over the midpoint of the BB. For canoeists, the device is placed on the same muscles on the front foot and performance arm, taking into account the paddling side.

DATA COLLECTION

The data were recorded in the computer using NIRS technology. Then, the values were determined by examining the data in the Procalysis program. The explanation of the values corresponding to the specified points in Figure 1 is given below, respectively:

STATISTICAL ANALYSIS

The level of significance was set at $p<0.05$ for experimental procedures. SPSS Statistics software (version 22, Armonk, NY: IBM Corp., ABD) was used for statistical analysis; the Bonferroni and repeated analysis of variance methods were used to compare and determine the differences of repeated measurements within and between the groups.

RESULTS

The research group consists of 30 licensed (international level; 11 rowers, 11 kayakers, 8 canoeist) male athletes who participated voluntarily in this study.

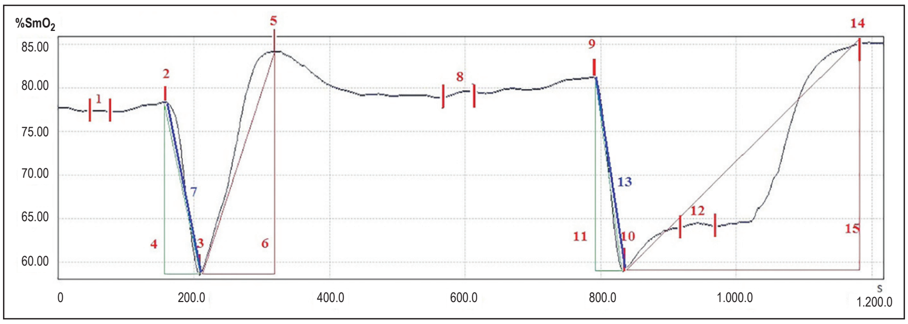

FIGURE 1: The marked points obtained as a result of the tests of the subjects in the Procalysis program that lasted approximately 22 minute. 1: Mean value of resting phase before 40 s sprint (30 s average), 2: 40 sec max value before sprint, 3: Minimum value during 40 sec sprint, 4: Decrement rate to minimum during 40 sec sprint, 5: Maximum value of reactive hyperemia after 40 sec sprint, 6: The difference between the maximum value of reactive hyperemia after 40 sec of sprint and the minimum value during 40 sec sprint, 7: The difference between the maximum value before 40 sec sprint and the minimum value during 40 sec sprint, 8: Mean value before 4 min distance test, 9: Maximum value before 4 min distance test, 10: Minimum value during 4 min distance test, 11: The difference between maximum value before 4 min distance test and minimum value during 4 min distance test, 12: Mean value during 4 min distance test, 13: Decrement rate to minimum during 4 min distance test, 14: Maximum value of reactive hyperemia after 4 min distance test, 15: The difference between the maximum value of reactive hyperemia after 4-min distance test and the minimum value during 4 min distance.

SmO_2: Muscle oxygen saturation; s: Second.

Significant differences between rowing, kayak and canoe branches according to our evaluation points are given in Table 1 and Table 2.

When we compare the canoe, kayak, and rowing athletes mean value of resting phase before 40 sec sprint, maximum SmO_2 values before 40-sec sprint significant differences were found between groups for both BB and VL, canoeist had a lower SmO_2 values than kayak and rowing athletes ($p<0.05$) (Table 1, Figure 2).

While there was a significant difference between reactive hyperemia values for BB after 40 sec sprint, caneist had a lower SmO_2 values than kayak and rowing athletes ($p<0.05$) (Table 1). There was a significant difference between reactive hyperemia values after 40 sec sprint and minimum SmO_2 values during 40 sec sprint between canoe, kayak and rowing, and there was a significant difference for BB. It was seen that the difference for BB was due to the difference between rowing and canoe branches, rowers had a higher

TABLE 1: Intramuscular oxygen saturation values for BB and VL obtained as a result of sprint (40 seconds) tests of canoe, kayak and rowing athletes, analysis of variance.

Evaluation point	p value
BB Mean value of resting phase before 40 sec sprint	0.007 *
BB 40 sec max value before sprint	0.003*
BB Minimum value during 40 sec sprint	0.866
BB Decrement rate to minimum during 40 sec sprint	0.424
BB The difference between the maximum value before 40 sec sprint and the minimum value during 40 sec sprint	0.429
BB Maximum value of reactive hyperemia after 40 sec sprint	0.001*
BB The difference between the maximum value of reactive hyperemia after 40 sec of sprint and the minimum value during 40 sec sprint	0.44*
VL Mean value of resting phase before 40 sec sprint	0.001*
VL 40 sec max value before sprint	0.001*
VL Minimum value during 40 sec sprint	0.034*
VL Decrement rate to minimum during 40 sec sprint	0.222
VL The difference between the maximum value before 40 sec sprint and the minimum value during 40 sec sprint	0.340
VL Maximum value of reactive hyperemia after 40 sec sprint	0.114
VL The difference between the maximum value of reactive hyperemia after 40 sec of sprint and the minimum value during 40 sec sprint	0.074

BB: Biceps brachii; VL: Vastus lateralis.

TABLE 2: Intramuscular oxygen saturation values for BB and VL obtained as a result of distance (4 minute) tests of canoe, kayak and rowing athletes, analysis of variance.

Evaluation point	p value
BB Mean value before 4 min distance test	0.005 *
BB Maximum value before 4 min distance test	0.036*
BB Minimum value during 4 min distance test	0.514
BB Decrement rate to minimum during 4 min distance test	0.001*
BB The difference between maximum value before 4 min distance test and minimum value during 4 min distance test	0.047*
BB Mean value during 4 min distance test	0.216
BB Maximum value of reactive hyperemia after 4 min distance test	0.001*
BB The difference between the maximum value of reactive hyperemia after 4 min distance test and the minimum value during 4 min distance.	0.001*
VL Mean value before 4 min distance test	0.003*
VL Maximum value before 4 min distance test	0.019*
VL Minimum value during 4 min distance test	0.015*
VL Decrement rate to minimum during 4 min distance test	0.005*
VL The difference between maximum value before 4 min distance test and minimum value during 4 min distance test	0.038*
VL Mean value during 4 min distance test	0.012*
VL Maximum value of reactive hyperemia after 4 min distance test	0.009*
VL The difference between the maximum value of reactive hyperemia after 4-min distance test and the minimum value during 4 min distance.	0.008*

BB: Biceps brachii; VL: Vastus lateralis.

SmO_2 than canoeist ($p<0.05$) (Table 1). There was a significant difference was found minimum value during 40 second sprint for VL. The difference is minimum SmO_2 values of kayak and rowing athletes were found higher decrement than canoeists ($p<0.05$) (Table 1).

There were significant differences among the groups for both muscles when we compare the SmO_2 values between the 10 min rest given before 4 min distance test and the resting average and maximum values taken here before the 4 min distance test. The resting mean values for VL before 4-min distance test were significantly different between canoe and rowing, also canoe and kayak ($p<0.05$) (Table 2, Figure 3).

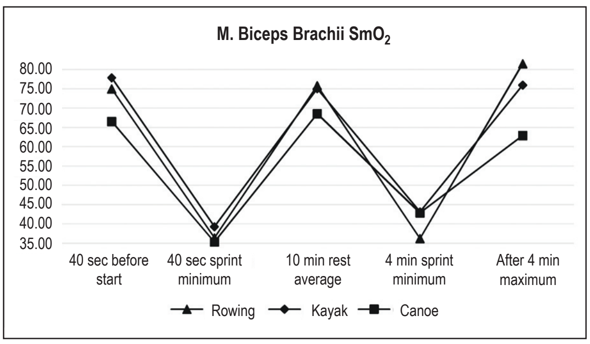

FIGURE 2: M. biceps brachii SmO_2% change of values for rowing, kayak and canoe branches during the test protocol.
SmO_2: Muscle oxygen saturation.

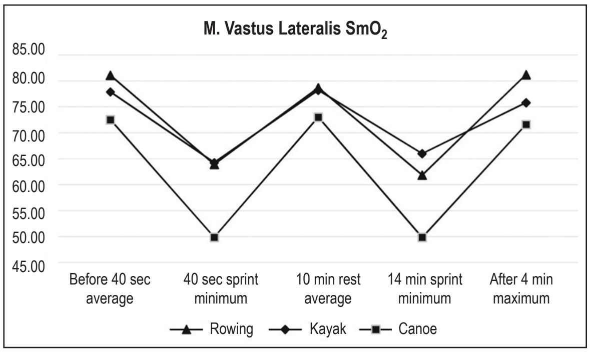

FIGURE 3: M. vastus lateralis SmO_2% change of values for rowing, kayak and canoe branches during the test protocol.
SmO_2: Muscle oxygen saturation.

There was significant difference for VL muscle between the minimum SmO_2 values of canoe, kayak and rowing athletes during 4 min distance test. The difference is minimum SmO_2 values of canoeists athletes were found lower decrement than kayak and rowing ($p<0.05$) (Table 2, Figure 3). When we compare the decrement rate minimum during 4 min distance test, there was a significant difference between branches for both muscle groups. When we examine this result in detail, it was seen that the difference for the BB and VL muscle was between rowing-canoe branches, rowers reached to the minimum SmO_2 value faster ($p<0.05$) (Table 2). There was a significant different the maximum resting SmO_2 value before 4 min distance test and minimum SmO_2 value during 4 min distance test between branches. When we examined the difference in detail, there was a significant difference between canoe and rowing for the BB muscle. For VL, a significant difference was found between kayak and canoe (p<0.05) (Table 2, Figure 3). The resting mean values for VL before 4 min distance test were significantly different between canoe and rowing and also canoe and kayak, canoeists had a lower SmO_2 than rowing and kayak athletes. There was a significant difference between reactive hyperemia values after 4 min distance test. When we examine the differences between the reactive hyperemia values after 4 min distance test and the minimum values during 4 min distance test, significant differences were found between canoe, kayak and rowing branches for both muscles BB and VL (p<0.05) (Table 2, Figure 3).

DISCUSSION

In this study, the differences between the effect of short (40 sec) and long (4 min) distance performance and resting SmO_2 values of the athletes in canoe, kayak and rowing were examined. Accordingly, it was thought that the significant differences observed between canoe and rowing athletes are generally due to the cardiovascular differences of the athletes among the branches, and especially that the rowers have a higher aerobic capacity than the canoeists, as shown in Table 3.

TABLE 3: VO_2max comparisons for canoe, kayak and rowing athletes.

Discipline	Author/s	VO_2max (L/min)	VO_2max (mL/kg/min)
Kayak	Paquette et al., 2018[14]	4.5	56.4
	Hahn et al., 1988[18]	4.62	58.5
	Fry and Morton, 1991[9]	4.78	58.9
	Billat et al., 1996[19]	4.01	53.8
Canoe	Paquette et al., 2018[14]	4.1	52.1
	Bunc and Heller, 1991[20]	4.17	51.9
Rowing	Zhang, 2010[21]	5.03	62.3
	Secher, 1983[22]	6	68.2
	Lakomy and Lakomy, 1993[23]	4.8	60

VO_2max: Maximum oxygen uptake.

In rowing, the quadriceps muscles, especially the vastus lateralis, are the main elements at the source of power generation, with their myoelectric activities increasing gradually with the increase in exercise intensity.[13] In addition, it can also be stated that different positions of rowing and canoe athletes have a negative effect on canoeists for their performance and resting positions in our study. Standing on the knees during rest and performance of canoeists and the difference in their balance stances can cause mechanical differences and differences in intramuscular oxygen saturation rates. There was no significant difference between rowing and kayak branches due to the similar SmO_2 results of the athletes. We think that the lack of significant difference is due to the fact that the resting positions of the rowing and kayak athletes are the same.

In another study, it was found that SmO_2 values for VL and BB muscles were higher in canoeists than in kayakers during short distance sprint (200 m).[14] In this study, differences were observed in the SmO_2 values taken during rest between kayak and canoe athletes.

We think that the decrease in SmO_2 values at the same rates during tests and the absence of a corresponding difference is due to the supramaximal (40 sec) and maximal (4 min) intensities of tests and the high intra-tissue oxygen consumption in each branch. When we compare the canoe, kayak and rowing branches at 40 sec sprint, it was seen that there were only differences between the rest values, and this difference was superior to the rowers, especially among the canoeists and rowers. When we compare the canoe, kayak and rowing branches at 4 min distance test, it was seen that there were significant differences in both rest and recovery values in both muscles, and this difference was in favor of rowers, especially among canoe and rowers.

Present studies also show that rowers a decrease in SmO_2 expressed as a difference from the resting value (from 51.5±2.7% for 10 min to 54.4±2.6% for 30 min) respectively, was recorded for VL muscle.[15] In our study, it was observed that the SmO_2 values of the BB muscles of rowers decrease to 51% for 40 seconds and to 52% for 4 minutes. Also for kayakers and canoeist we seen that similar decreasing on the BB

(Figure 2). For VL there is a less decrease SmO_2 values to when athletes perform on the 40 sec and 4 min (Figure 3). We think that it can be less decrease to SmO_2 values of the athletes perform shorter time on the our test protocol. Also it is thought that increased cardiac output due to maximal (40 sec) and supmaximal (4 min) loading affects SmO_2.[14]

SmO_2 displays the dynamic equilibrium between oxygen transport to and oxygen utilization in tissue.[16] This interplay and complexity may be the major cause for the weaker classificatory accuracy of SmO_2 for the different body postures.[17] The results show that intramuscular oxygen saturation it can be said that many factors effect such as differences between branches, posture position, cardiovascular differences between athletes, using of body parts, and number of stroke per minute.[7,14,17]

CONCLUSION

The results of our study show the differences in intramuscular oxygen saturation in short and long distance performances of lower and upper extremity muscles, which are used extensively in canoe, kayak and rowing branches. The ability to monitor intramuscular oxygen saturation with wearable devices allows the athletes to monitor intramuscular oxygen dynamics, especially during the general preparation period, and accordingly, it also allows the trainers to follow the performance increase, capillarization and tissue oxidation. Therefore, trainers can follow the performance of their athletes from the laboratory environment to the field environment by non-invasive method with intramuscular oxygen saturation.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Mehmet Topal, Serdar Orkun Pelvan;* ***Design:*** *Mehmet Topal, Serdar Orkun Pelvan;* ***Control/Supervision:*** *Mehmet Topal, Serdar Orkun Pelvan;* ***Data Collection and/or Processing:*** *Mehmet Topal, Serdar Orkun Pelvan, Savaş Akbaş;* ***Analysis and/or Interpretation:*** *Mehmet Topal, Serdar Orkun Pelvan, Savaş Akbaş;* ***Literature Review:*** *Mehmet Topal;* ***Writing the Article:*** *Mehmet Topal, Serdar Orkun Pelvan, Savaş Akbaş;* ***Critical Review:*** *Mehmet Topal, Serdar Orkun Pelvan, Savaş Akbaş.*

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