Fenerbahçe Üniversitesi
Spor Bilimleri Dergisi
Cilt 3, Sayı 3, 13-39, 2023
Fenerbahce University
Journal of Sport Science
Volume 3, Issue 3, 13-39, 2023
FBU-JSS e-ISSN: 2791-7096

Özgün Araştırma / Research Article

INVESTIGATION OF THE EFFECTS OF DIFFERENT EXERCISE MODELS ON HEART RATE VARIABILITY AND MUSCLE OXYGEN SATURATION

Hilal KALKAN[1] , Orkun PELVAN[2]

ABSTRACT

The aim of the study was to investigate heart rate variability response and muscle oxygen saturation during and after different exercise patterns with similar heart rate ranges in athletes of different body region dominant sports (lower extremity and whole body), namely rowing and long-middle distance running.

Eighteen volunteer male athletes competing in rowing and running participated in the study. The athletes performed a gradually increasing exercise test on the first day and a 6-minute exercise test at an individually calculated target heart rate on the second day.

In the target heart rate test, RR values for the first 2 minutes were higher in runners ($p<0.05$). When a comparison was made between the two groups, it was found that muscle oxygen saturation values of both muscles were higher in the running group in the 1st minute ($p<0.05$). During post-test recovery, the intragroup RR values of both groups differed in the first 90 seconds ($p<0.05$).

The results of the study show that the autonomic control processes during the acute recovery period are qualitatively different between muscle groups of different sizes trained with different exercise types in exercises with similar HR levels. RR values, especially during the fast phase of recovery, support this view.

Keywords: Heart Rate, Heart Rate Variability, Muscle Oxygen Saturation, Different Types of Exercise

FARKLI EGZERSİZ MODELLERİNİN KALP ATIM HIZI DEĞİŞKENLİĞİ VE KAS OKSİJEN DOYGUNLUĞU ÜZERİNDEKİ ETKİLERİNİN İNCELENMESİ

ÖZET

Çalışmanın amacı; kürek ve uzun-orta mesafe koşu olmak üzere, farklı vücut bölgeleri baskın (alt ekstremite ve tüm vücut) spor branşlarındaki sporcuların, benzer nabız aralıklarındaki farklı egzersiz modelleri sırasında ve sonrasındaki kalp atım hızı değişkenliği yanıtı ile kas oksijen doygunluğunu incelemektir.

Araştırmaya kürek ve koşu branşlarında yarışan 18 gönüllü erkek sporcu katılmıştır. Sporcular ilk gün kademeli olarak artan bir egzersiz testi ve ikinci günde ise bireysel olarak hesaplanan hedef nabızda 6 dakikalık bir egzersiz testi gerçekleştirmiştir.

Hedef nabız testinde iki grup arasında ilk 2 dakika RR değerleri koşucularda daha yüksektir ($p<0.05$). İki grup arasında karşılaştırma yapıldığında her iki kasa ait kas oksijen doygunluğu değerlerinin 1. dakikada koşu grubunda daha yüksek olduğu saptanmıştır ($p<0.05$). Test sonrası toparlanma sırasında her iki grubun grup içi RR değerleri ilk 90 saniyede farklılık göstermiştir ($p<0.05$).

Çalışmanın sonuçları, benzer KAH seviyelerine ulaşılan egzersizlerde, akut toparlanma dönemindeki otonomik kontrol süreçlerinin, farklı egzersiz türleriyle çalıştırılan farklı büyüklükteki kas grupları arasında niteliksel olarak farklı olduğunu göstermektedir. Özellikle toparlanmanın hızlı aşamasındaki RR değerleri, bu görüşü desteklemektedir.

Anahtar Kelimeler: Kalp Atım Hızı, Kalp Atım Hızı Değişkenliği, Kas Oksijen Doygunluğu, Farklı Egzersiz Türleri

[1] Marmara Üniversitesi, Sağlık Bilimleri Enstitüsü, Beden Eğitimi ve Spor Anabilim Dalı, İstanbul/TÜRKİYE. hilalkalkanpv@gmail.com, ORCID iD: 0000-0003-2476-4956
[2] Marmara Üniversitesi, Spor Bilimleri Fakültesi, Spor Sağlık Bilimleri Anabilim Dalı, İstanbul/TÜRKİYE. orkunpelvan@gmail.com, ORCID iD: 0000-0001-7809-0788

13

1.INTRODUCTION

Running performance is determined by factors such as maximal oxygen consumption (VO_2max), the ability to maintain a high percentage of VO_2max over long periods of time, and running economy. Especially in long-distance running such as marathons, the interaction of complex factors such as a high cardiac output and efficient oxygen delivery to the muscles is critical. In this context, the ability to maintain a high percentage of VO2max over long periods of time and running economy are important in explaining running performance (Foster & Lucia, 2007). In rowing, performance depends on physiological and metabolic processes such as anaerobic threshold, MaxVO2 and maximum lactate production (Bourdin, 2004). Rowing and middle-long distance running have similar physiological parameters in this context. Although these sports branches have unique biomechanical characteristics, the main difference between the branches is that runners predominantly use the lower extremity, while rowers use both extremities during exercise. The dominant use of different body regions during rowing and running suggests that these two groups may have different power outputs and different physiological values during exercise and recovery.

Nowadays, non-invasive measurement methods such as heart rate (HR) and muscle oxygen saturation (SMO2 - %) have gained popularity for monitoring sportive performance (da Mota Moreira et al., 2023). SMO2 data provide indirect information about oxidative metabolism (Ferrari et al., 1997). Decreasing SMO2 values during exercise are a marker of increased workload and thus oxygen consumption (Şayli et al., 2011). Heart rate variability (HRV) is a measure reflecting time changes between consecutive heartbeats and is an output of dynamic nonlinear autonomic nervous system processes. Analysis of HRV can provide indirect information about the autonomic function of the cardiovascular system and allows us to assess sympathetic and parasympathetic activity. Currently, HRV has become one of the most useful tools used to monitor the time course of athletes' training adaptation and maladaptation and to adjust optimal training loads leading to performance enhancement (Dong, 2016). Although HRV has been used in clinical areas for a long time, its use in sports sciences has gained popularity in recent years. For this reason, studies investigating the effect of different types of exercise on HRV are not sufficient and show conflicting results (Leicht et al., 2008, Cottin et al., 2004, Kiss et al., 2016, Kingsley and Figueroa, 2016, Yoshiga and Higuchi, 2002, Hung et al., 2020, Toprakoglu, 2021, Dong, 2016). Despite the conflicting results, the data suggest that HRV may differ in sports where different body regions are predominantly used. In addition, existing studies suggest that different body region-dominant exercises may have different power outputs and thus different HRV responses, even when performed at the same heart rate. However, there is no study that examined HRV and SMO2 together in different extremity-dominated sports such as rowing and running.

The aim of the study was to examine the heart rate variability response and SMO2 during and after different exercise patterns at similar heart rate intervals in athletes of different body region dominant sports (lower extremity and whole body), including rowing and long-medium distance running. In this context, the main hypotheses of the study were that there is a difference between heart rate variability and muscle oxygen saturation values during and after different exercise patterns at similar heart rate intervals.

2. METHOD

This study was approved by Ethics Committee on 02.08.2022 with protocol number 09.2022.1054. An oral presentation was made with the title "Investigation of the Effects of Different Exercise Models on Heart Rate Variability and Muscle Oxygen Saturation" at the 9th International Conference on Science Culture and Sport held in Prague / Czechia between September 11-14, 2023. This project was also supported by the Wellness Institute Turkey.

The population of the study consisted of elite rowing and track and field athletes (middle distance running) living in Turkey. The demographic characteristics of the athletes are detailed in Table 1. The sample of the study was selected by simple random sampling among the athletes who train at least 4 days a week in one of the rowing and athletics sports, who have been active and licensed athletes for at least 3 years in one of the specified branches, who have participated in the Turkish Championship at least once and who do not have any health problems. The sample group consisted of 18 athletes, 8 athletics (running) and 10 rowing athletes.

Two different tests were administered to the athletes on two different days. Resting RR (the time between successive heart beats in milliseconds) and SMO2 values of the athletes were taken before the test on both measurement days. Resting data were taken while the athletes were in supine position wearing headphones for sound isolation and an eye patch for light isolation (Photograph 1). In all tests performed in the study, runners used a treadmill (Skillrun, Technogym, IT) (Photograph 2) and rowers used a rowing ergometer (Concept 2 PM5, USA) (Photograph 3).

On the first day, demographic information of the athletes was recorded. Then, a gradually increasing exercise test was performed, until the athletes were exhausted, on rowing and running ergometers to learn the maximum heart rate of the athletes. On the rowing ergometer, the test started with 150 Watts and increased by 30 Watts every minute. On the running ergometer, the test started at 10 km/h and increased by 1 km/h every minute. The maximum heart rate of the athletes on the first day of the test and the resting heart rate on the second day were taken and the target heart rate at 80% exercise intensity was calculated with the Karvonen formula shown below (Karvonen et al., 1957).

Target Heart Rate = (Maximum Heart Rate - Resting Heart Rate) * Exercise Intensity + Resting Heart Rate

On the second day, the athletes performed the 6-minute test at the predetermined target heart rate (2 minutes at the target heart rate, 4 minutes at the target heart rate) after a 20-minute warm-up and 5 minutes of rest. Then immediately after the test, the athletes went to the supine position within 10 seconds and performed a 15-minute recovery. During recovery, the athletes wore headphones and eye patches to avoid being affected by sound and light (Photograph 1).

RR data, a parameter of HRV, were measured with a heart rate chest strap (Polar H10) and SMO2 data were measured with a wireless and portable near infrared spectroscopy (NIRS) (Train.Red FYER Sensors, NL) (da Mota Moreira et al., 2023) device. The NIRS devices were placed on the most bulging part of the Biceps Brachii muscle with the dominant arm of the volunteer at a 90-degree angle and the M.Vastus Lateralis muscle on the lateral side of the M.Quadriceps Femoris muscle, 15 cm away from the patella, (Akbaş, 2017). The recorded RR data were analyzed in Kubios KAHV and SMO2 data were analyzed in Procalysis program. Reactive hyperemia differences were calculated by subtracting the point at which muscle was the lowest at the end of the exercise from the point at which SMO2 was the maximum, which increased rapidly at the end of the exercise.

Jamovi program was used for statistical analysis. First, the minimum, maximum, mean and standard deviation values of all descriptive physical and physiological parameters were taken. The mean RR, M. Vastus Lateralis and Biceps Brachii SMO2 values between groups in the rest, test and recovery periods of both days were analyzed using Paired Sample T-Test. Repeated Measures ANOVA test was used for within-group differences.

Photograph 1: Obtaining Resting and Post-Test Recovery Data

Photograph 2: Treadmill Test

Photograph 3: Testing on a Rowing Ergometer

3. FINDINGS

Table 1: Descriptive Statistics Table of Demographic Data of Athletes

Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
Age (year)	Rowers	10	23.00	3.8586	18	30
	Runners	8	25.38	7.1502	18	37
Height (m)	Rowers	10	1.88	0.0698	1.77	2.00
	Runners	8	1.79	0.0650	1.64	1.83
Weight (kg)	Rowers	10	82.20	10.6646	70	100
	Runners	8	66.38	8.3655	52	76
Body Mass Index (BMI)	Rowers	10	23.30	2.4757	20.02	28.29
	Runners	8	20.77	1.7073	18.81	23.41

Table 2: Comparison of Demographic Data Between Groups (Only statistically significant differences are given in the table (p<0.05))

Paired Samples T-Test

			statistic	df	p
Height (Rowers)	Height (Runners)	Student's t	2.528	7.00	0.039
Weight (Rowers)	Weight (Runners)	Student's t	3.611	7.00	0.009
BMI (Rowers)	BMI (Runners)	Student's t	2.932	7.00	0.022

(p<0.05)

According to demographic data; height, weight and Body Mass Index (BMI) values were found to be higher in rowers (p<0.05) (Tables 1 and 2).

Table 3: Descriptive Statistics Table of Mean RR and SMO2 Values for the First and Second Day Rest

Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
1. Day RR	Rowers	10	1106.2	132.46	932.3	1361.9
	Runners	8	1110.9	129.30	919.5	1302.7
2. Day RR	Rowers	10	1177.3	137.73	1000.1	1408.4
	Runners	8	1192.5	249.84	953.2	1728.8
2. Day Biceps	Rowers	10	61.5	3.98	55.3	66.4
	Runners	8	61.9	5.39	52.8	68.6
2. Day Vastus	Runners	10	65.2	4.39	56.1	71.4
	Rowers	8	63.8	2.87	57.3	67.0

Table 4: Comparison of Data on Resting between Groups

Paired Samples T-Test

			statistic	df	p
1.Day RR Runners	1.Day RR Rowers	Student's t	0.2447	7.00	0.814
2.Day RR Runners	2.Day RR Rowers	Student's t	0.3719	7.00	0.721
1.Day Biceps Runners	1.Day Biceps Rowers	Student's t	0.0633	7.00	0.951
1.Day Vastus Runners	1.Day Vastus Rowers	Student's t	-1.5214	7.00	0.172
2.Day Biceps Runners	2.Day Biceps Rowers	Student's t	-0.1061	7.00	0.919
2.Day Vastus Runners	2.Day Vastus Rowers	Student's t	-0.8616	7.00	0.417

($p<0.05$)

There was no difference between the first and second day resting values of the running and rowing groups (Tables 3 and 4).

Table 5: Descriptive Statistics Table for Wattage Completed, Time and Calculated Target Heart rate in Gradually Increasing Exercise Test

Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
Watt	Rowers	10	432.0	25.30	390	480
	Runners	8	228.8	29.36	179	271
Time (second)	Rowers	10	630.0	50.99	540	720
	Runners	8	727.5	103.61	540	840
Targer Heart Rate (bpm)	Rowers	10	163.7	3.92	156	170
	Runners	8	160.6	7.41	148	167
Speed (m/s)	Runners	8	21.1	1.73	18	23

Table 6: Comparison of Gradually Increasing Exercise Test Data Between Groups

Paired Samples T-Test

			statistic	df	p
Watt-Rowers	Watt-Runners	Student's t	14.511	7.00	< .001
Target Heart Rate-Rowers	Target Heart Rate-Runners	Student's t	0.884	7.00	0.406
Time-Rowers	Time-Runners	Student's t	-1.984	7.00	0.088

(p<0.05)

According to the results of the gradually increasing exercise test, it was determined that the Watt values of the rowing group were higher than the running group (p<0.01) (Tables 5 and 6).

Table 7: Descriptive Statistics Table for Target Heart Rate Test RR Values

Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
RR-60 s	Rowers	10	443	20.57	415	479
	Runners	8	551	65.22	448	661
RR-120 s	Rowers	10	370	11.35	359	394
	Runners	8	398	33.16	365	463
RR-180 s	Rowers	10	363	8.76	349	375
	Runners	8	374	18.49	359	404
RR-240 s	Rowers	10	365	10.19	349	385
	Runners	8	371	14.62	357	397
RR-300 s	Rowers	10	364	9.41	353	383
	Runners	8	371	13.67	359	398
RR-360 s	Rowers	10	364	10.28	353	382
	Runners	8	370	11.80	359	394

Table 8: Comparison of RR Values for Target Heart Rate Test between Groups

Paired Samples T-Test

			statistic	df	p
60 s RR-Runners	60 s RR-Rowers	Student's t	5.33	7.00	0.001
120 s RR- Runners	120 s RR-Rowers	Student's t	3.39	7.00	0.012
180 s RR- Runners	180 s RR-Rowers	Student's t	2.22	7.00	0.062
240 s RR- Runners	240 s RR-Rowers	Student's t	1.29	7.00	0.238
300 s RR- Runners	300 s RR-Rowers	Student's t	2.84	7.00	0.025

Paired Samples T-Test

			statistic	df	p
360 s RR- Runners	360 s RR-Rowers	Student's t	1.91	7.00	0.097

($p<0.05$)

In the target heart rate test, the RR values of the running group differed in the first 3 minutes, while the rowing group differed in the first 2 minutes ($p<0.05$). Between the two groups, the first 2 minutes RR values were higher in the runners ($p<0.05$) (Tables 7, 8 and Graph 1).

Table 9: Post-Test Recovery RR Values at Target Heart rate

Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
30 s	Rowers	10	425	51.2	369	555
	Runners	8	455	31.6	415	493
60 s	Rowers	10	543	65.1	453	684
	Runners	8	695	48.6	631	758
90 s	Rowers	10	608	73.7	549	793
	Runners	8	800	80.5	634	882
120 s	Rowers	10	625	63.9	550	761
	Runners	8	839	113.8	670	1069
150 s	Rowers	10	646	70.4	562	802
	Runners	8	822	86.0	695	922
180 s	Rowers	10	666	62.3	578	768
	Runners	8	801	73.1	683	924
210 s	Rowers	10	682	64.9	587	782
	Runners	8	815	68.9	731	950
240 s	Rowers	10	694	65.8	605	816
	Runners	8	812	54.8	745	926

Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
270 s	Rowers	10	708	60.2	625	822
	Runners	8	832	61.5	777	951
300 s	Rowers	10	718	76.9	618	898
	Runners	8	840	87.2	740	965
330 s	Rowers	10	741	88.3	630	954
	Runners	8	857	92.1	748	995
360 s	Rowers	10	747	68.7	666	898
	Runners	8	861	96.1	745	1009
390 s	Rowers	10	744	68.9	638	882
	Runners	8	863	80.3	787	994
420 s	Rowers	10	758	87.4	647	943
	Runners	8	865	86.5	748	987
450 s	Rowers	10	765	83.1	670	944
	Runners	8	862	97.4	727	1004
480 s	Rowers	10	787	79.6	699	954
	Runners	8	873	96.0	769	1018
510 s	Rowers	10	799	80.9	692	963
	Runners	8	889	93.2	775	1027
540 s	Rowers	10	802	76.1	691	913
	Runners	8	890	87.5	806	1033
570 s	Rowers	10	790	63.7	703	902
	Runners	8	893	124.4	762	1123
600 s	Rowers	10	784	60.0	695	917
	Runners	8	904	104.2	781	1048

Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
630 s	Rowers	10	804	69.6	700	940
	Runners	8	896	110.3	768	1069
660 s	Rowers	10	813	78.4	704	980
	Runners	8	906	121.4	808	1147
690 s	Rowers	10	796	84.4	698	1001
	Runners	8	909	112.8	798	1122
720 s	Rowers	10	795	74.6	715	977
	Runners	8	909	113.1	799	1118
750 s	Rowers	10	809	86.3	707	984
	Runners	8	904	103.5	793	1071
780 s	Rowers	10	825	88.0	709	1005
	Runners	8	912	112.6	795	1116
810 s	Rowers	10	819	90.0	698	1022
	Runners	8	931	117.7	816	1162
840 s	Rowers	10	834	84.4	732	1021
	Runners	8	950	109.0	816	1154
870 s	Rowers	10	819	77.5	725	986
	Runners	8	936	109.0	764	1114
900 s	Rowers	10	804	54.9	732	926
	Runners	8	923	93.7	799	1062

Table 10: Comparison of RR Values for Post-Test Recovery at Target Heart Rate between Groups (Only statistically significant differences are given in the table (p<0.05))

Paired Samples T-Test

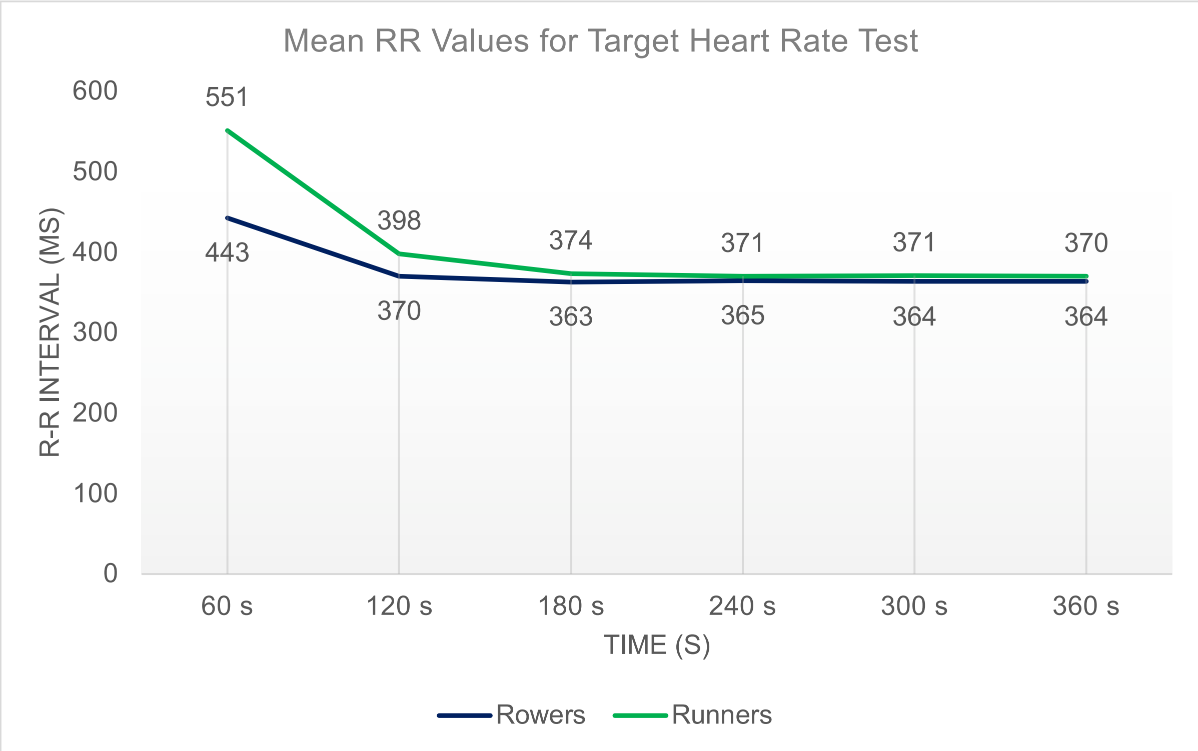
			Statistic	df	p
60s-Rowers	60s-Runners	Student's t	-4.323	7.00	0.003
90s-Rowers	90s-Runners	Student's t	-4.430	7.00	0.003
120s-Rowers	120s-Runners	Student's t	-4.821	7.00	0.002
150s-Rowers	150s-Runners	Student's t	-5.336	7.00	0.001
180s-Rowers	180s-Runners	Student's t	-5.635	7.00	< .001
240s-Rowers	240s-Runners	Student's t	-5.549	7.00	< .001
270s-Rowers	270s-Runners	Student's t	-6.293	7.00	< .001
300s-Rowers	300s-Runners	Student's t	-2.911	7.00	0.023
330s-Rowers	330s-Runners	Student's t	-2.560	7.00	0.038
360s-Rowers	360s-Runners	Student's t	-2.689	7.00	0.031
390s-Rowers	390s-Runners	Student's t	-3.465	7.00	0.010

Paired Samples T-Test

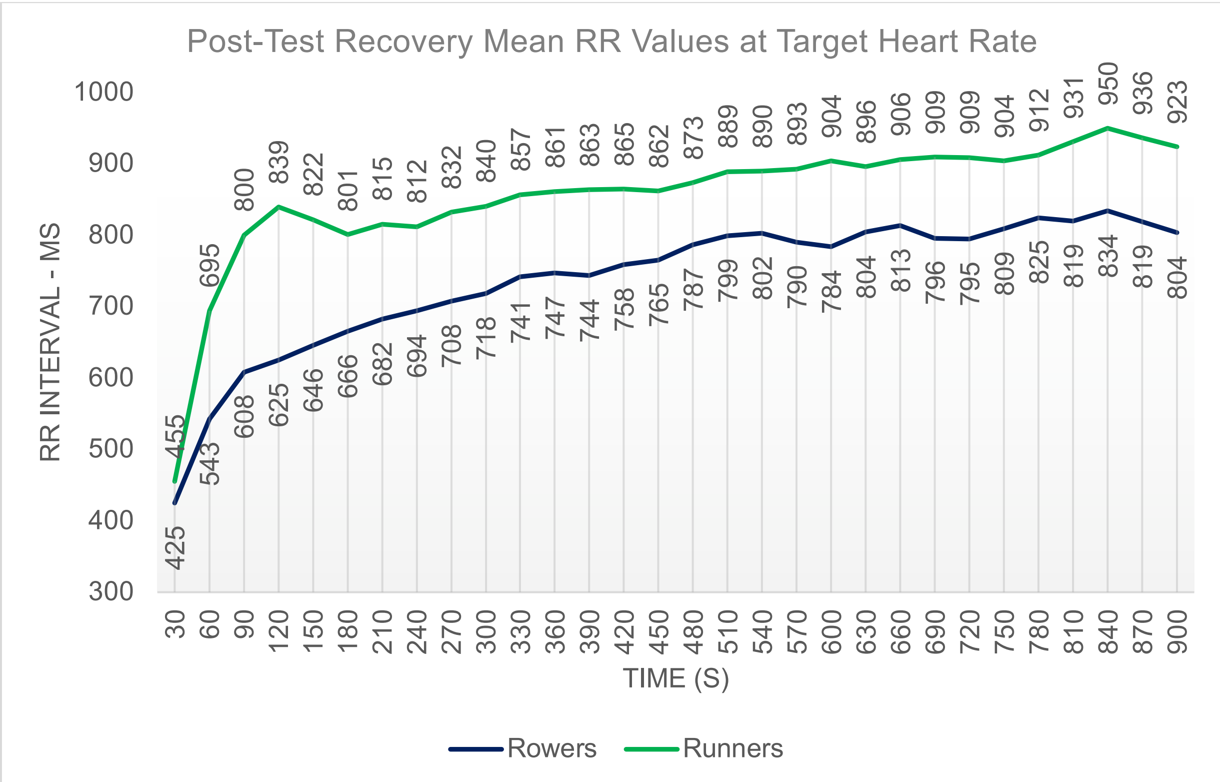
			Statistic	df	p
420s-Rowers	420s-Runners	Student's t	-3.512	7.00	0.010
570s-Rowers	570s-Runners	Student's t	-2.393	7.00	0.048
600s-Rowers	600s-Runners	Student's t	-2.890	7.00	0.023
630s-Rowers	630s-Runners	Student's t	-2.415	7.00	0.046
870s-Rowers	870s-Runners	Student's t	-3.105	7.00	0.017
900s-Rowers	900s-Runners	Student's t	-3.638	7.00	0.008

($p<0.05$)

During post-test recovery, the intragroup RR values of both groups differed in the first 90 seconds ($p<0.05$). Between 60-420, 570-630 and 870-900 seconds, the RR values of the running group were higher than the rowing group ($p<0.05$) (Tables 9, 10 and Graph 2).



Graph 1: Mean RR Values for Target Heart Rate Test



Graph 2: Post-Test Recovery Mean RR Values at Target Heart Rate

Fenerbahçe Üniversitesi
Spor Bilimleri Dergisi
Cilt 3, Sayı 3, 13-39, 2023
Fenerbahce University
Journal of Sport Science
Volume 3, Issue 3, 13-39, 2023
FBU-JSS e-ISSN: 2791-7096

Table 11: Descriptive Statistics Table for SMO2 Values of Target Heart Rate Test

	Grup	N	Mean	SD	Minimum	Maximum
Biceps-60 s	Rowers	10	51.7	4.26	46.8	59.4
	Runners	8	60.3	4.69	55.3	68.8
Biceps-120 s	Rowers	10	46.2	4.64	38.8	54.4
	Runners	8	46.9	8.03	38.1	61.5
Biceps-180 s	Rowers	10	47.9	4.48	40.6	55.4
	Runners	8	42.6	11.41	21.7	58.7
Biceps-240 s	Rowers	10	48.2	3.60	43.9	53.5
	Runners	8	44.9	9.69	24.8	56.9
Biceps-300 s	Rowers	10	47.6	3.49	43.3	52.6
	Runners	8	48.4	6.44	36.4	56.8
Biceps-360 s	Rowers	10	46.9	4.23	41.3	53.2
	Runners	8	50.7	6.27	39.7	57.0
Vastus-60 s	Rowers	10	55.3	5.29	45.3	66.5
	Runners	8	61.6	4.01	56.3	70.1
Vastus-120 s	Rowers	10	50.3	5.63	43.3	62.4
	Runners	8	54.3	6.51	42.3	62.1
Vastus-180 s	Rowers	10	51.2	5.34	43.5	62.0
	Runners	8	53.8	6.34	42.0	60.9
Vastus-240 s	Rowers	10	52.0	5.33	43.3	61.5
	Runners	8	53.8	5.72	43.0	59.9
Vastus-300 s	Rowers	10	51.8	5.66	42.2	62.2
	Runners	8	53.5	5.63	43.1	58.6
Vastus-360 s	Rowers	10	51.4	5.82	41.1	62.1
	Runners	8	53.2	5.17	44.4	59.2

Table 12: Comparison of SMO2 Values of Target Heart Rate Test between Groups (Only statistically significant differences are given in the table (p<0.05))

Paired Samples T-Test

			statistic	df	p
60s-Biceps-Runners	60s-Biceps-Rowers	Student's t	3.893	7.00	0.006
60s-Vastus-Runners	60s-Vastus-Rowers	Student's t	3.859	7.00	0.006

(p<0.05)

Biceps Brachii muscle SMO2 values differed in the 1st and 2nd minutes in the running group, 1st 2nd and 3rd minutes in the rowing group and Vastus Lateralis muscle SMO2 values differed in the 1st and 2nd minutes in the rowing group (p<0.05). When a comparison was made between the two groups, it was found that SMO2 values of both muscles were higher in the running group at the 1st minute (p<0.05) (Tables 11, 12 and Graph 3).

Table 13: Post-Test Recovery Reactive Hyperemia Difference and Times at Target Heart Rate

Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
M. Biceps B. SMO2 Difference %	Rowers	10	22.9	4.58	18	31
	Runners	6	13.0	10.24	5	32
M. Biceps Brachii Reaktive Hyperemia Time (s)	Rowers	10	174.2	63.91	87	300
	Runners	6	221.5	101.09	125	404
M. Vastus Lateralis SMO2 Difference %	Rowers	10	18.2	6.27	11	31
	Runners	7	16.9	6.18	9	25
M. Vastus L. Reaktive Hyperemia Time (s)	Rowers	10	236.4	190.14	80	666
	Runners	7	305.1	174.31	163	596

Table 14: Comparison of Post-Test Recovery Reactive Hyperemia Differences and Times at Target Heart Rate between Groups (Only statistically significant differences are given in the table)

Paired Samples T-Test

			statistic	df	p
Runner's Biceps Reaktive Hyperemia Difference	Rowers's Biceps Reaktive Hyperemia Difference	Student's t	-2.849	5.00	0.036
Runner's Vastus Reaktive Hyperemia Time	Rowers's Vastus Reaktive Hyperemia Time	Student's t	2.898	6.00	0.027

($p<0.05$)

In the reactive hyperemia after the test, the difference in SMO2 of the Biceps Brachii muscle was higher in the rowing group, while the duration of reactive hyperemia in the Vastus Lateralis muscle was higher in the runners ($p<0.05$) (Table 13, 14 and Graph 4).

Table 15: Post-Test Recovery SMO2 Values at Target Heart Rate

Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
Biceps 60 s	Rowers	10	59.1	6.39	50.1	68.4
	Runners	8	58.1	4.84	48.9	64.0
Biceps 120 s	Rowers	10	63.1	6.56	55.1	75.6
	Runners	8	60.9	4.88	53.8	67.8
Biceps 180 s	Rowers	10	62.0	5.40	54.8	71.3
	Runners	8	61.8	5.72	53.1	71.9
Biceps 240 s	Rowers	10	61.9	4.59	54.5	69.6
	Runners	8	62.4	4.56	55.0	69.3

Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
Biceps 300 s	Rowers	10	62.5	4.70	55.5	69.9
	Runners	8	62.6	4.34	55.8	68.5
Biceps 360 s	Rowers	10	63.2	4.91	56.1	70.6
	Runners	8	62.3	3.77	56.5	68.3
Biceps 420 s	Rowers	10	63.8	5.05	55.1	70.9
	Runners	8	62.4	3.77	56.6	68.8
Biceps 480 s	Rowers	10	63.6	5.10	54.9	71.3
	Runners	8	63.3	3.71	57.7	69.1
Biceps 540 s	Rowers	10	63.1	4.77	55.4	70.0
	Runners	8	62.7	4.16	56.4	68.8
Biceps 600 s	Rowers	10	63.6	4.63	55.9	70.7
	Runners	8	62.8	3.32	58.2	68.2
Biceps 660 s	Rowers	10	63.3	4.11	56.8	69.8
	Runners	8	63.1	3.59	57.5	68.7
Biceps 720 s	Rowers	10	64.1	4.40	56.7	72.1
	Runners	8	63.2	3.72	57.9	69.4
Biceps 780 s	Rowers	10	63.2	3.99	57.4	70.4
	Runners	8	63.6	4.03	57.6	69.9
Biceps 840 s	Rowers	10	63.7	3.78	58.5	70.0
	Runners	8	63.4	4.27	57.0	70.1
Biceps 900 s	Rowers	10	64.2	4.20	58.0	71.2
	Runners	8	63.9	4.01	58.3	70.3
Vastus 60 s	Rowers	10	60.6	6.37	49.1	68.1
	Runners	8	58.9	2.99	53.9	61.9

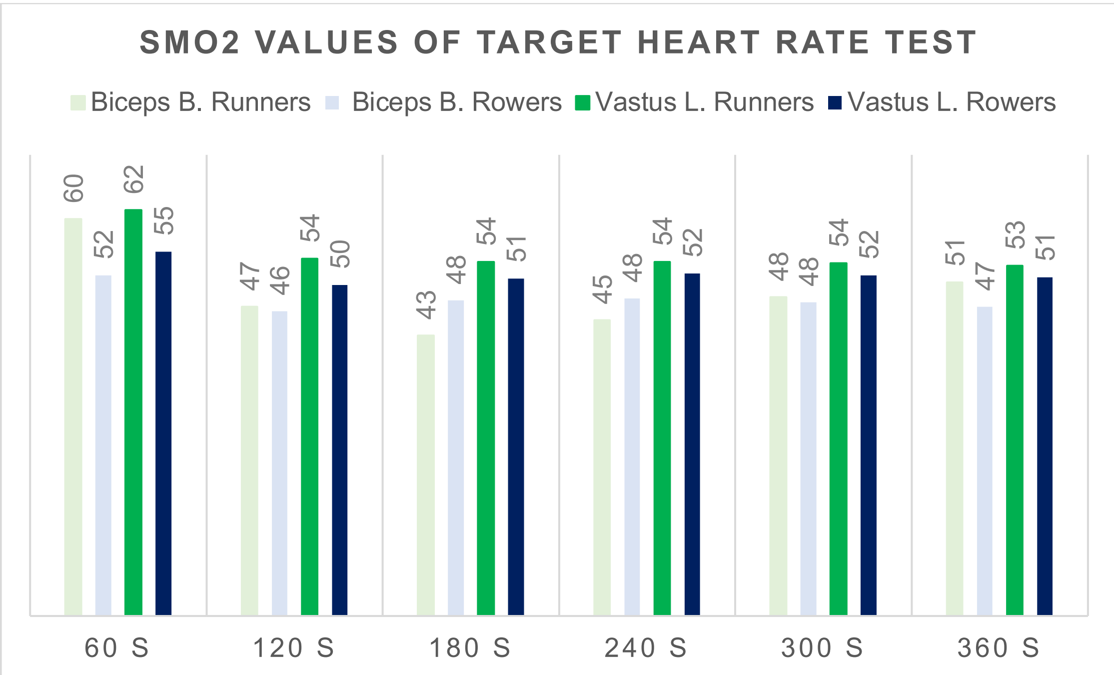
Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
Vastus 120 s	Rowers	10	67.2	6.74	52.3	77.8
	Runners	8	62.8	2.57	58.3	66.6
Vastus 180 s	Rowers	10	68.0	6.20	55.1	77.4
	Runners	8	64.8	1.75	61.2	67.3
Vastus 240 s	Runners	10	68.1	5.99	55.7	76.9
	Rowers	8	65.4	2.14	62.1	68.3
Vastus 300 s	Rowers	10	68.2	6.00	55.8	76.7
	Runners	8	65.3	2.44	61.9	68.6
Vastus 360 s	Rowers	10	68.2	6.20	55.4	76.9
	Runners	8	65.7	2.76	61.2	69.5
Vastus 420 s	Rowers	10	68.3	6.37	55.0	76.8
	Runners	8	66.1	2.85	61.6	69.8
Vastus 480 s	Runners	10	68.3	6.30	55.6	77.0
	Rowers	8	66.2	2.61	62.2	69.9
Vastus 540 s	Rowers	10	68.3	6.25	55.8	77.0
	Runners	8	66.3	2.94	61.9	70.6
Vastus 600 s	Rowers	10	68.4	6.19	56.0	77.0
	Runners	8	66.2	2.66	62.2	70.8
Vastus 660 s	Rowers	10	68.3	6.15	56.4	77.0
	Runners	8	66.2	2.70	61.8	70.6
Vastus 720 s	Rowers	10	68.3	6.20	56.4	77.0
	Runners	8	66.4	2.61	62.6	70.5
Vastus 780 s	Rowers	10	68.4	6.17	56.6	77.0
	Runners	8	66.6	2.63	62.5	70.5

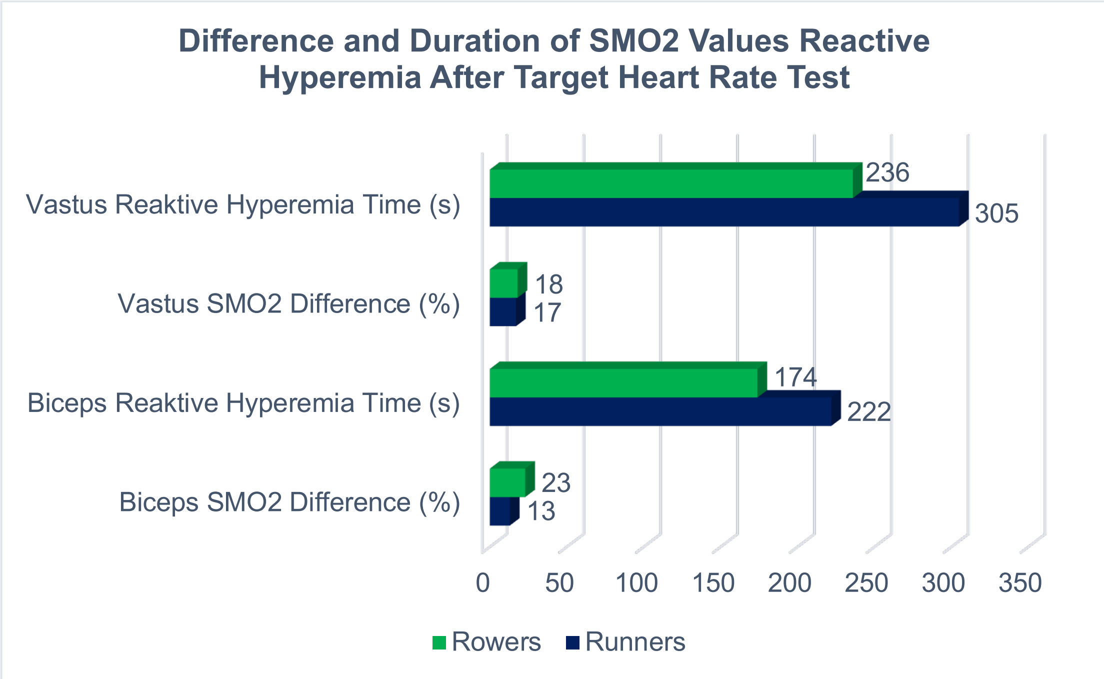
Descriptives

	Grup	N	Mean	SD	Minimum	Maximum
Vastus 840 s	Rowers	10	68.5	6.18	56.8	76.9
	Runners	8	66.4	2.17	63.2	69.5
Vastus 900 s	Runners	10	68.5	6.22	56.9	77.0
	Rowers	8	66.4	2.10	63.3	69.3

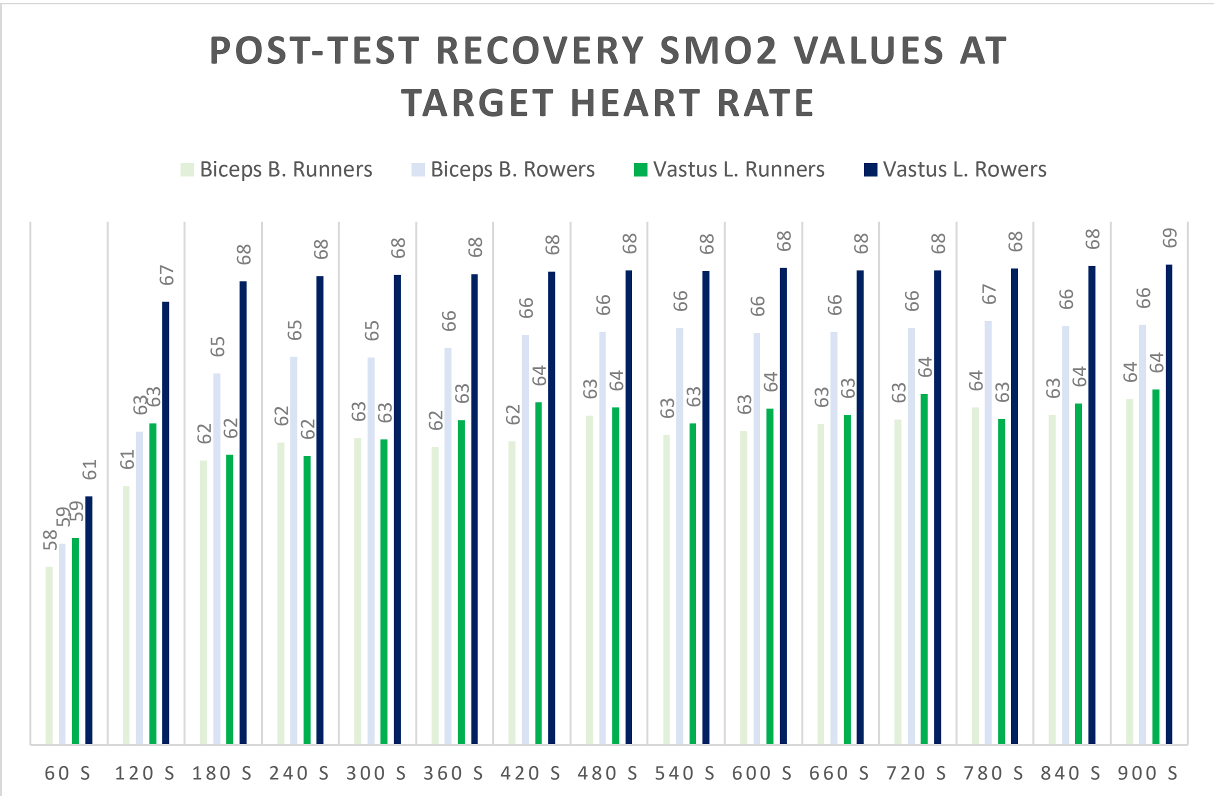
Post-recovery Vastus Lateralis muscle SMO2 values differed between 1st and 2nd minutes in runners and rowers, while Biceps Brachii muscle SMO2 values differed between 1st and 2nd minutes only in rowers ($p<0.05$). In addition, there was no significant difference in post-recovery SMO2 values between the groups (Table 15 and Graph 5).



Graph 3: SMO2 Values of Target Heart Rate Test



Graph 4: Difference and Duration of SMO2 Values Reactive Hyperemia After Target Heart Rate Test



Graph 5: Post-Test Recovery SMO2 Values at Target Heart Rate

4. DISCUSSION and CONCLUSION

In our study, no difference was found between the first and second day RR and SMO2 values of the two groups (**Table 4**).

There was no difference between the groups in the gradually increasing exercise test HR values. Although the Watt values reached by the groups were different, the RR values between the groups were similar. Yoshiga and Higuchi (2002) observed that during rowing at maximum intensity, HR was lower than during running at maximum intensity. In this context, our findings are inconsistent with this study. This may be because the cardiovascular system responded similarly to the increased workload during the test in both groups. However, the target heart rate values calculated between the groups were similar. This allowed the comparison of different exercise models with similar heart rate ranges in the target heart rate test.

During the target heart rate test, the rowing group showed lower RR (**Tables 7, 8 and Graph 1**) and SMO2 (**Tables 11, 12 and Graph 3**) values and reached the desired target heart rate earlier.

After the test, we found that the RR values of the rowing group were lower (**Tables 9, 10 and Graph 2**) and the SMO2 values of both groups were similar (**Table 15 and Graph 5**). However, we found that the rowing group had a higher reactive hyperemia difference in the Biceps Brachii muscle and a shorter duration of reactive hyperemia in the Vastus Lateralis muscle than the running group (**Tables 13, 14 and Graph 4**).

The human body is basically an organism developed to maintain homeostasis. This situation does not change in exercise. The circulatory system, nervous system and respiratory system maintain balance with mechanisms that compensate for increased metabolic acidosis in the body. During exercise, there is a need to increase the blood supply to skeletal muscle due to increased oxygen demand as a result of muscle activity and also to remove metabolic wastes. The heart is supplied by sympathetic and parasympathetic nerves. Sympathetic nerves are concentrated in all parts of the heart, especially in the ventricles. This is important so that more blood can be pumped with increased stimulation when necessary. More blood pumped through the ventricle means more pressure. The increase in pressure forces blood into the blood vessels and dilates them, reducing resistance and increasing blood flow. The microvessels of each tissue control the supply of oxygen and nutrients and the accumulation of wastes such as carbon dioxide. This system first affects local vessels, causing dilatation or constriction. This is very important for oxidative metabolism, but the energy required for muscle contraction must somehow be supplied from ATP derived from oxygen and various cellular nutrients. In prolonged contractions, 95% of energy is obtained in this way. In exercise, skeletal muscles contract and compress all blood vessels, directing blood to the heart and lungs. Cardiac output increases 5-7 times. Increased skeletal muscle metabolism results in vasodilation of muscle arterioles. Thus, the necessary oxygen and nutrients can be supplied to the muscle for the continuation of contraction. In summary, with exercise, the sympathetic nervous system stimulates the entire circulation, increasing arterial pressure and cardiac output (Guyton and Hall, 2007).

Considering the findings of the study, it can be said that the rowing group had higher heart rates and lower muscle oxygen saturation levels than the running group during the target heart rate test. Lower RR values mean higher heart rate. Although the heart rate of both groups decreases at similar times during recovery, it is noticeable that the heart rate of the rowing group is higher than the running group. This means that heart rate variability after rowing exercise is lower than running. In addition, although the SMO2 levels of the two groups were similar during recovery, the rowing group had a higher difference in Biceps Brachii reactive hyperemia and a shorter duration of Vastus Lateralis reactive hyperemia. And these results are statistically significant (**Tables 13, 14 and 15**).

Recovery of heart rate after exercise is mediated by both parts of the autonomic nervous system. The initial heart rate decline is initiated by parasympathetic reactivation and sympathetic withdrawal (Pierpont and Voth, 2004; Borrosen et al., 2008; Imai et al., 1994). The acute heart rate recovery process is usually analyzed in two phases; the fast phase refers to a phase that covers the first minute and represents the parasympathetic reactivation phase (Fecchio et al., 2019). In this context, in our study, although the fast recovery times were similar (90 seconds) in exercises with similar heart rate ranges, RR values showed statistically significant differences in the fast and slow phase recovery periods (**Table 10**).

We think that the differences found in the study are primarily due to the muscle groups used at different intensities. During rowing exercise, both extremities were used predominantly, whereas only the lower extremities were used predominantly during running. At the same time, height, weight and BMI values of the rowing group were higher than those of the running group (**Tables 1 and 2**).

It has been shown that the increased sympathetic activity during isometric exercises is due to the amount of muscle mass used. This is also true for isotonic exercise. Hung et al. reported that sympathetic activity increases more in lower body exercises than in upper body exercises due to the difference in the load used (Hung et al., 2020). The data obtained in the target heart rate test are consistent with this study.

The number of muscle groups and muscle mass used predominantly by the rowing group is higher than the other group. The intense load of exercise on the whole body may lead to increased metabolite formation due to anaerobic metabolism and mechanical occlusion. This leads to increased afferent firing frequencies of muscle chemoreceptors, which in turn leads to increased sympathetic activation of the cardiac excitation and conduction system through a mechanism called metaboreflex. At the same time, metabolites accumulated in active skeletal muscles stimulate afferent nerves and chemoreceptors in the carotid trunk. This stimulation is then known as the metaboreflex, a mechanism that increases sympathetic nerve activity leading to a reflex increase. Epinephrine released into the systemic circulation during exercise can cause further sympathetic stimulation, which in turn can suppress cardiac parasympathetic reactivation. Post-exercise parasympathetic activity is significantly associated with post-exercise plasma epinephrine levels, blood lactate concentrations, blood acidosis and arterial oxygenation (Buchheit et al., 2007; Buchheit et al., 2010; Buchheit et al., 2011). Increased sympathetic stimulation in exercise increases the heart rate and force of heart contraction. Physical exercise is associated with parasympathetic decline and increased sympathetic activity leads to an increase in heart rate (Guyton and Hall, 2007). Although this leads to increased blood flow to the muscles, the oxygen demand in muscle tissue will increase with the increase in muscle workload. The increased demand can lead to faster oxygen depletion. Oxygen depletion can lead to anaerobic energy production. This will lower the pH level, first in the muscle and then in the blood. In order to normalize the lowered pH, circulation needs to be accelerated. As a result, an increase in HR can be expected. Intensive use of the whole body in exercise, with more muscle groups participating in the exercise, may mean a further decrease in intramuscular pH and a further increase in HR.

In addition, although the target heart rate test was performed at similar heart rate intervals, the Watt values reached by the rowing group during exercise were higher than the running group (**Tables 5 and 6)**. This result is an indication of a higher power output in rowing exercise. Since higher power output would require more resources for ATP production, it may have contributed to the pH decrease. More oxygen will be needed to tolerate the lower pH and the heart will beat faster and stronger.

Muscle oxygen saturation data provide indirect information about oxidative metabolism (Ferrari et al., 1997). Decreasing SMO2 values during exercise are indicative of increased workload and thus oxygen consumption (Şayli et al., 2011). The combined use of upper and lower extremity muscle groups in the rowing group, participation of more active muscle groups in the exercise, higher BMI values and higher power output may have led to lower SMO2 values in the rowing group during the test and therefore to reach oxygen saturation faster during recovery. In this case, we think that besides systemic reasons such as cardiac response time, factors that shift the hemoglobin dissociation curve to the right in exercise (pCO2 increase, H+ concentration increase, pH decrease) are also effective. As the shift of the curve to the right will facilitate the separation of oxygen from hemoglobin, more oxygen will be supplied to the tissues. The fact that rowers showed lower SMO2 values during the test and reached reactive hyperemia faster during recovery may be due to such circumstances. Also, a higher oxygen consumption in muscle tissue during rowing exercise may be another explanation for the higher heart rate in post-exercise recovery.

The results of the study suggest that the autonomic control processes during the acute recovery period are qualitatively different between muscle groups of different sizes trained with different types of exercise, when similar levels of HR are reached. RR values, especially during the fast phase of recovery, support this view. Although the present study provides information about the acute recovery processes of different exercise types, it suggests that future studies should be conducted with a larger measurement group, different exercise types and different methods.

REFERENCES

Akbaş, S. (2017). Kablosuz yakın kızılaltı spektroskopisinin güvenirliği ve geçerliği (Master's thesis, Sağlık Bilimleri Enstitüsü).

Borresen J, Lambert MI. (2008). Autonomic Control of Heart Rate during and after Exercise. Sports Med. 38, 633–646.

Bourdin M, Messonnier L. (2004). Laboratory blood lactate profile is suited to on water training monitoring in highly trained rowers. J Sports Med Phys Fitness, 44(4): 337-41.

Buchheit M, Chivot A, Parouty J. (2010) Monitoring endurance running performance using cardiac parasympathetic function. Eur J Appl Physiol. 108, 1153–1167.

Buchheit M, Voss SC, Nybo L, Mohr M, Racinais S. (2011) Monitoring responses to training in the heat. Scand J Med Sci Sports. 21: 477-485

Arthur C. Guyton, John E. Hall. (2007). Tıbbi Fizyoloji (Prof. Dr. Hayrunnisa Çavuşoğlu, Prof. Dr. Berrak Çağlayan Yenen) İstanbul, Yüce Yayımları & Nobel Tıp Kitabevleri Ltd. Şti.

Cottin F, Durbin F, Papelier Y. (2004). Heart rate variability during cycloergometric exercise or judo wrestling eliciting the same heart rate level. Eur J Appl Physiol 91:177–184

da Mota Moreira, I., Willigenburg, T. R., Kregting, W. J., Van Steijn, E. R., FloorWesterdijk, M. J., & Colier, W. N. (2023). Assessing stability and accuracy of a novel commercial wearable near-infrared spectroscopy device. In Biophotonics in Exercise Science, Sports Medicine, Health Monitoring Technologies, and Wearables IV (Vol. 12375, pp. 75-84). SPIE.

Dong, J. G. (2016). The role of heart rate variability in sports physiology. Experimental and therapeutic medicine, 11(5), 1531-1536.

Fecchio RY, Brito L, Leicht AS, Forjaz CLM, Peçanha T. (2019). Reproducibility of postexercise heart rate recovery indices: A systematic review. Autonomic Neuroscience. 221: 102582.

Ferrari, M., Binzoni, T., & Quaresima, V. (1997). Oxidative metabolism in muscle. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 352(1354), 677-683.

Foster, C., & Lucia, A. (2007). Running economy. Sports medicine, 37(4), 316-319

Hung, C. H., Clemente, F. M., Bezerra, P., Chiu, Y. W., Chien, C. H., Crowley-McHattan, Z., & Chen, Y. S. (2020). Post-Exercise recovery of ultra short-term heart rate variability after yoyo intermittent recovery test and repeated sprint ability test. International Journal of Environmental Research and Public Health, 17(11), 4070.

Imai K, Sato H, Hori M, Kusuoka H, Ozaki H, Yokoyama H, Takeda H, Inoue M, Kamada T. (1994). Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. J Am Coll Cardiol. 24: 1529–1535.

Karvonen MJ, Kentala E, MustalA O. (1957) The effects of training on heart rate; a longitudinal study. Ann Med Exp Biol Fenn. 35:307–15.

Kingsley, J. D., & Figueroa, A. (2016). Acute and training effects of resistance exercise on heart rate variability. Clinical physiology and functional imaging, 36(3), 179-187.

Kiss, O., Sydó, N., Vargha, P., Vágó, H., Czimbalmos, C., Édes, E., ... & Merkely, B. (2016). Detailed heart rate variability analysis in athletes. Clinical Autonomic Research, 26(4), 245- 252.

Leicht, A. S., Sinclair, W. H., & Spinks, W. L. (2008). Effect of exercise mode on heart rate variability during steady state exercise. European journal of applied physiology, 102(2), 195- 204.

Pierpont GL, Voth EJ. (2004) Assessing autonomic function by analysis of heart rate recovery from exercise in healthy subjects. The American Journal of Cardiology, 94: 64- 68.

Şayli Ö, Biçer B, Uzun S, Pelvan O, Akın A, Çotuk B. (2011). Yakın kızılaltı spektroskopi ve yüzeyel elektromiyografi kullanarak kas yorgunluğu inceleme çalışmaları, MÜSBED 1(1): 17- 25.

Toprakoğlu, Sercan. (2021). Farkli egzersiz tiplerinin egzersiz sonrasi toparlanma sirasinda kalp atim hizi değişkenliğine etkisinin incelenmesi. (Master's thesis, Marmara Üniversitesi Sağlık Bilimleri Enstitüsü).

Yoshiga, C. C., & Higuchi, M. (2002). Heart rate is lower during ergometer rowing than during treadmill running. European Journal of Applied Physiology, 87(2), 97-100.