THE EFFECT OF TRANSCUTANEOUS AURICULAR VAGUS NERVE STIMULATION ON CYCLING ERGOMETRY AND RECOVERY IN HEALTHY YOUNG INDIVIDUALS

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Abstract

It is aimed to examine the potential benefits and effects of the use of transcutaneous auricular vagus nerve stimulation for sporting purposes on recovery, fatigue and sportive performance level. This study 90 people between the ages of 18-23 participated. They were randomly divided into 3 groups as control, unilateral and bilateral vagus nerve stimulation (VSS). Cycling exercise was performed with maximum performance for 30 minutes under the same wattage load. Pulse, systolic and diastolic blood pressure, distance, pain, fatigue, lactic acid level and autonomic nervous system were evaluated before, after and at the end of the cycling exercise. In the comparison made within the group, there was a statistically significant difference between the data in all groups except for the distance covered parameter ($p<0.05$). When we compare the groups, in addition to the distance traveled in all groups, there is no statistically significant difference in the 1st day 1st measurement or 2nd measurement data of all parameters ($p>0.05$). When we compared the data according to the days, there was a statistically significant difference only between the pain and fatigue levels ($p<0.05$). When we compared the groups, it was found that bilateral VSS had favorable results compared to other applications. When we evaluated the data on a daily basis, similar results were obtained. We are of the opinion that it will be of maximum benefit for the athlete to be applied, especially during and after the half-time of the competition. Keywords: Vagus Nerve Stimulation, Transcutaneous, Auricular, Recovery, Cycling Ergometry

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VAGUS NERVE STIMULATION ON RECOVERY

It is aimed to examine the potential benefits and effects of the use of transcutaneous auricular vagus nerve stimulation for sporting purposes on recovery, fatigue and sportive performance level. This study 90 people between the ages of 18-23 participated. They were randomly divided into 3 groups as bilateral sham stimulation, unilateral and bilateral vagus nerve stimulation (VSS). Cycling exercise was performed with maximum performance for 30 minutes under the same wattage load. Pulse, systolic and diastolic blood pressure, distance, pain, fatigue, lactic acid level and autonomic nervous system were evaluated before, after and at the end of the cycling exercise. In the comparison made within the group, there was a statistically significant difference between the data in all groups except for the distance covered parameter ($p<0.05$). When we compare the groups, in addition to the distance traveled in all groups, there is no statistically significant difference in the 1st day 1st measurement or 2nd measurement data of all parameters ($p>0.05$). When we

compared the data according to the days, there was a statistically significant difference only between the pain and fatigue levels ($p<0.05$). When we compared the groups, it was found that bilateral VSS had favorable results compared to other applications. When we evaluated the data on a daily basis, similar results were obtained. We are of the opinion that it will be of maximum benefit for the athlete to be applied, especially during and after the half-time of the competition.

Keywords: Vagus Nerve Stimulation, Transcutaneous, Auricular, Recovery, Cycling Ergometry

The structure that controls the involuntary functioning and functions of the internal organs in our body is the autonomic nervous system. It has a key role in maintaining homestasis. Generally, the sympathetic system regulates catabolic events, while the parasympathetic system regulates anabolic events (McCorry, 2007). The vagus nerve is the most innervating cranial nerve in the body. This nerve carries sensory, motor and parasympathetic information. The task of the nerve is to activate the parasympathetic system and support the 'rest and digest' process to provide homestasis (Karemaker, 2017; Koopman et al., 2011).

Stimulation of the vagus nerve is the stimulation of the nerve by manual or electrical stimulation. For manual stimulation of the vagus nerve, massage and compression are applied on the carotid artery in the neck region. Later, with the development of technology, electrical stimulation methods began to be used. In the method that uses electrical stimulation, invasive and non-invasive applications are made. Non-invasive applications reduce the risk of infection and provide easy application (Howland, 2014; Lanska, 2002).

Today, with the professionalization of sports as a result of globalization, sports activities have lost their characteristics of being games. For this reason, the capitalist economic order has dominated sports. Football, one of the most popular sports branches, has become a multi-million dollar industry with revenues such as broadcasting, advertising, sponsorship and matchdays (Uhrich, 2021; Galariotis et al., 2018). With the industrialization of sports, more competition means more income. In addition, during these competitions, athletes are required to perform at a high level. For these reasons, sports clubs and athletes are looking for different methods in order to reduce the level of fatigue in a short time and accelerate recovery.

As a result of the literature study we have done, it is aimed to examine the potential benefits and effects of the use of transcutaneous auricular vagus nerve stimulation for sports purposes, which will be applied due to the high level of performance expectation from the athletes and the increasing number of competitions, on the recovery, fatigue and sportive performance level of the athletes.

MATERAIL AND METHODS

Desing of the study

It is a single-blind randomized clinical trial, including pre-test and post-test evaluation methods, in which the evaluator was blinded.

Subjects

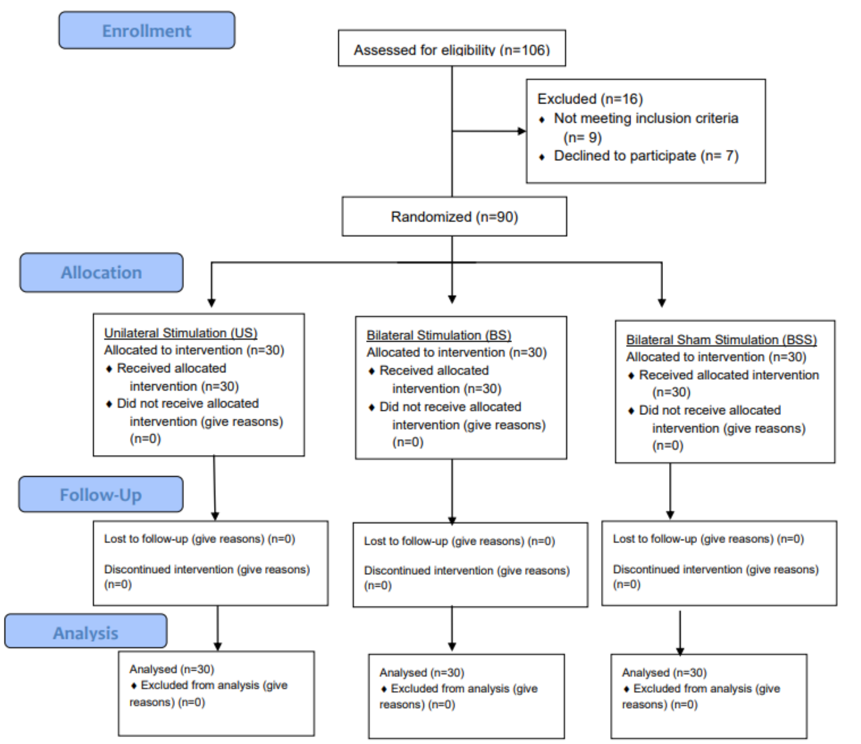
In this study, 106 volunteer healthy individuals between the ages of 18-35 participated in the laboratory of Sinop University, Türkeli Vocational School. Inclusion criteria for the study; (1) Being healthy between the ages of 18-35, (2) Volunteering to participate in the study, (3) Signing a voluntary consent form, (4) Being in the inactive category according to the International Physical Activity Questionnaire. Exclusion criteria from the study; (1) Having regular sports habits, (2) Being pregnant or suspected of pregnancy, (3) Disability of the lower or upper extremities, (4) Acute wound or infection in the ear. (5) Those who are in the very minimally active or active category according to the International Physical Activity questionnaire, (6) Presence of any chronic disease and drug use for this condition, (7) Current history of respiratory system disease, and receiving treatment, (8) existing cardiac system disease history and receiving treatment, (9) existing hearing system disease history and receiving treatment.

After informing the participants of the study in detail about the procedure to be applied, an international physical activity questionnaire was first applied to the volunteers who signed the consent form (Van Poppel et al., 2010). Out of 106 people evaluated for eligibility, 4 people with regular sports habits, 5 people in the active category according to the results of the international physical activity survey, 7 people who refused to participate in the study, and 90 participants were continued. The gender, age, height, weight and body mass indexes of the participants who met the inclusion criteria were recorded and randomly divided into 3 groups. No one left the study for any reason after randomization.

A 4-day protocol was used in the study. Cycling exercise was done with maximum performance for 30 minutes under the same watt load for four days. At the end of the cycling exercise, non-invasive auricular stimulation was performed with the Vagustim device according to the groups of the participants. The distances they traveled were recorded for comparison. It was evaluated with 7 different parameters before and after cycling exercise and at the end of vagus nerve stimulation every day.

Simple size

In order to determine the number of samples, power analysis was performed using the G*Power (v3.1.9.7) program. The power of the study is expressed as 1-β (β = probability of type II error). In Liu et al.'s (2017) study evaluating the heart rate variability predicting the response to vagus nerve stimulation in patients with drug-resistant epilepsy, the measurement data of the control group (1064±562) and the data of the epileptic patient group, based on the mean and standard deviation values of LF Power, are (608±406) scores were reached (Liu et al, 2017). The effect size (d) was found to be 0.348 in the calculation made to obtain 80% power at the α=0.05 level of the study. Accordingly, it was determined that there should be 84 people in total for this study, which has 3 groups.



Outcome measures

Primary outcome measures

The fatigue level of the participants was evaluated by fatigue rating scale (Micklewright, et al. 2017) and lactic acid level (Tanner, et al. 2010), pain by numerical pain scale (Farrar, et al. 2001), autonomic nervous system by HRV analysis with a wearable chest strap (Perrotta, et al. 2017), and performance by measuring distance covered on a bicycle ergometer.

Secondary outcome measures

The secondary evaluation in the study, on the other hand, evaluated the pulse and blood pressure values of the participants with a blood pressure device on the right wrist.

Interventions

In our study, it was applied non-invasively by giving ear stimulation using single ear, double ear and earphones specially produced for control application (Kutlu, et al. 2020). Stimulation was done from Vagustim device (Vagustim, Istanbul, TURKEY) at 10 Hz frequency, biphasic, 300 microsecond pulse width and modulation mode. In the adjustment of the flow intensity, it was applied for 20 minutes by keeping the value that the subject felt at the comfort limit constant.

Randomization

The subjects participating in the study were assigned numbers from 1 to 90. Simple random sampling method was used. A number sequence consisting of 30 numbers was produced for each group from the Microsoft Office Excel program. Groups were formed with the generated number sequence.

Permission

The study was the appropriate plan of the Declaration of Helsinki. Before starting the study, ethics committee approval dated 29.09.2021 and numbered 2021/6 was obtained from Gümüşhane University Scientific Research and Publication Ethics Committee. The trial was registered with the ClinicalTrials.gov registry (Study Identifier: NCT05778058).

Data Analysis

While evaluating the findings obtained in the study, IBM SPSS Statistics 22 program was used for statistical analysis. The suitability of the parameters to the normal distribution was evaluated by Kolmogorov-Smirnov and Shapiro Wilks tests. The Oneway Anova test was used to compare the parameters with normal distribution between groups, and the Tukey HDS test was used if the variances of the groups were homogeneous, and Tamhane's T2 test was used if they were not homogeneous. Kruskal Wallis test was used for the comparison of the parameters that did not show normal distribution, and Dunn's test was used to determine the group that caused the difference. Analysis of variance was used for repetitive measurements, Bonferroni test was used as post hoc test for the comparisons of the normally distributed parameters. The Friedman test was used for the intragroup comparisons of the parameters that did not show normal distribution, and the Wilcoxon sign test was used as the post hoc test. Continuity (Yates) Correction was used to compare qualitative data. Significance was evaluated at the $p<0.05$ level.

RESULTS

There was no significant difference between the demographic data of the groups before the application (Table 1).

In the evaluation made after VSS application on all days and at the 24th hour after the application, the fatigue values of the US and BS groups decreased significantly compared to the BSS group. In addition, the fatigue values of the BS group decreased significantly compared to the US group in the evaluation made after the 2nd and 4th day VSS application and at the 24th hour after the 2nd day application. Considering the changes within the group after the vagus application; fatigue values decreased significantly in all groups on all days (Table 2).

The pain scores of the BS group decreased significantly compared to the US and control groups in the evaluation made after the 1st, 3rd day and 4th day VSS application and at the 24th hour after the 3rd day application. In the evaluation made after the 2nd day VSS application and at the 24th hour after the

1st day/2nd day application, the pain scores of the US and BS groups decreased significantly compared to the BSS group, while the pain scores of the BS group decreased significantly compared to the US group. Considering the changes within the group after the VSS application; pain scores decreased significantly in all groups on all days (Table 2).

After the VSS application, the lactic acid values of the BS group decreased significantly compared to the US and BSS groups. However, there was no significant difference between the other groups and in the evaluation made at the 24th hour after the application. Considering the intragroup changes in the evaluation made after the VSS application and at the 24th hour after the application; lactic acid values decreased significantly in all groups (Table 3).

No significant difference was found in the distance parameter in both between-group and in-group analyzes (Table 3).

RMSSD and PNN50 values of the BS group increased significantly compared to the US and BSS groups in the evaluation made after the VSS application and at the 24th hour after the VSS application. In addition, after the VSS application, the RMSSD and PNN50 values of the US group increased significantly compared to the BSS group (Table 4).

After the VSS application, the HF values of the BS and US groups increased significantly compared to the BSS group. In addition, the HF values of the BS group increased significantly compared to the US group. In the evaluation made at the 24th hour after the VSS application, the HF values of the BS group increased significantly compared to the BSS group. However, no significant difference was found between the other groups (Table 4).

Considering the intragroup changes in the evaluation made after the VSS application and at the 24th hour after the VSS application; RMSSD, PNN50 and HF values increased significantly in all groups (Table 4).

After the VSS application, the LF values of the BS and BSS groups decreased significantly compared to the US group. However, there was no significant difference between the other groups and in the evaluation made at the 24th hour after the VSS application (Table 4).

In the evaluation made after the VSS application and at the 24th hour after the VSS application, the LF/HF ratio values of the BS and US groups decreased significantly compared to the BSS group. In addition, the LF/HF ratio values of the BS group were significantly lower than the US group (Table 4).

Considering the intragroup changes in the evaluation made after the VSS application and at the 24th hour after the application; LF and LF/HF ratio values decreased significantly in all groups (Table 4).

After VSS application on all days, the pulse and systolic pressure values of the US and BS groups decreased significantly compared to the BSS group. On all days, the heart rate and systolic pressure values of the BS group (except the 1st day) were significantly lower than the US group. In addition, diastolic pressure values of the BS group decreased significantly compared to the BSS group after VSS application on all days (Table 5).

In the evaluation made at the 24th hour after the 1st day VSS application, the pulse values of the BS group were significantly lower than the BSS group. However, there was no significant difference between the other groups and in the 2nd day/3rd/4th day evaluation (Table 5).

Considering the changes within the group after the VSS application; pulse and systolic/diastolic pressure values decreased significantly in all groups on all days (Table 5).

Table 1

Parameters	**Mean±SD**	**Mean±SD**	**Mean±SD**	p
	US	**BS**	**BSS**	
AGE	20,1±1,06	20,4±0,89	20,57±1,55	0,317

Parameters	Mean±SD	Mean±SD	Mean±SD	p
HEIGHT	1,69±0,1	1,69±0,08	1,7±0,08	0,929
WEIGHT	66,1±13,85	63,6±8,98	63,4±12,91	0,630
BMI	22,96±4,06	22,16±2,52	21,78±3,26	0,377
F/M	15/15	15/15	15/15	$^{+}$1,000

Oneway ANOVA Test, +Continuity (yates) correction.

Tablo 2

Parameters	Parameters	Parameters	Mean±SD (Median)	Mean±SD (Median)	Mean±SD (Median)	^{1}p
			US	**BS**	**BSS**	
Fatigue (0-10)	**1st day**	**1st measurement**	0±0 (0)^{A}	0±0 (0)^{A}	0±0 (0)^{A}	1,000^{K}
		2nd measurement	7,47±1,14 (8)^{A}	7,57±0,97 (8)^{A}	7,37±1,16 (8)^{A}	0,843^{K}
		3rd measurement	4,67±1,03 (5)^{A}	3,97±0,81 (4)^{A}	6,53±1,04 (6)^{B}	0,001^{K,*}
		^{2}p	0,001^{F,*}	0,001^{F,*}	0,001^{F,*}	
	2nd day	**1st measurement (24th hour)**	2,97±0,72 (3)^{A}	2,63±0,56 (3)^{A}	6,20±1,06 (6)^{B}	0,001^{K,*}
		2nd measurement	7,87±0,86 (8)^{A}	6,77±0,86 (7)^{B}	8,03±0,72 (8)^{A}	0,001^{K,*}
		3rd measurement	4,70±1,09 (4,5)^{A}	3,20±0,76 (3)^{B}	6,5±0,63 (6,5)^{C}	0,001^{K,*}
		^{2}p	0,001^{F,*}	0,001^{F,*}	0,001^{F,*}	
	3rd day	**1st measurement**	2,73±0,69 (3)^{A}	2,00±0,53 (2)^{B}	3,93±0,94 (4)^{C}	0,001^{K,*}
		2nd measurement	7,73±0,74 (8)^{A}	6,57±0,94 (7)^{B}	7,83±0,65 (8)^{A}	0,001^{K,*}
		3rd measurement	5,20±0,61 (5)^{A}	2,83±0,65 (3)^{B}	5,47±0,94 (5,5)^{A}	0,001^{K,*}
		^{2}p	0,001^{F,*}	0,001^{F,*}	0,001^{F,*}	
	4th day	**1st measurement**	2,67±0,66 (3)^{A}	1,77±0,63 (2)^{B}	3,03±0,72 (3)^{A}	0,001^{K,*}
		2nd measurement	7,80±0,71 (8)^{A}	6,17±0,91 (6)^{B}	8,00±0,98 (8)^{A}	0,001^{K,*}
		3rd measurement	4,70±0,65 (5)^{A}	2,80±0,71 (3)^{B}	5,87±1,11 (6)^{C}	0,001^{K,*}
		^{2}p	0,001^{F,*}	0,001^{F,*}	0,001^{F,*}	
Pain (0-10)	**1st day**	**1st measurement**	0±0 (0)^{A}	0±0 (0)^{A}	0±0 (0)^{A}	1,000^{K}
		2nd measurement	7,53±0,51 (8)^{A}	7,30±0,47 (7)^{A}	7,57±0,73 (8)^{A}	0,116^{K}
		3rd measurement	5,43±0,5 (5)^{A}	4,27±0,58 (4)^{B}	5,93±0,78 (6)^{A}	0,001^{K,*}

Parameters	Parameters	Parameters	Mean±SD (Median)	Mean±SD (Median)	Mean±SD (Median)	^{1}p
		^{2}p	$0,001^{F,*}$	$0,001^{F,*}$	$0,001^{F,*}$	
	2nd day	**1st measurement (24th hour)**	3,57±0,63 $(3,5)^{A}$	2,90±0,8 $(3)^{B}$	4,37±0,81 $(4)^{C}$	$0,001^{K,*}$
		2nd measurement	6,97±0,67 $(7)^{A}$	6,63±0,85 $(7)^{A}$	6,97±0,67 $(7)^{A}$	$0,161^{K}$
		3rd measurement	4,90±0,71 $(5)^{A}$	3,37±0,49 $(3)^{B}$	5,57±0,63 $(5,5)^{C}$	$0,001^{K,*}$
		^{2}p	$0,001^{F,*}$	$0,001^{F,*}$	$0,001^{F,*}$	
	3rd day	**1st measurement**	3,53±0,51 $(4)^{A}$	2,57±0,5 $(3)^{B}$	4,20±0,66 $(4)^{C}$	$0,001^{K,*}$
		2nd measurement	7,30±0,47 $(7)^{A}$	5,33±0,61 $(5)^{B}$	7,17±0,70 $(7)^{A}$	$0,001^{K,*}$
		3rd measurement	5,40±0,50 $(5)^{A}$	3,03±0,72 $(3)^{B}$	5,87±0,63 $(6)^{A}$	$0,001^{K,*}$
		^{2}p	$0,001^{F,*}$	$0,001^{F,*}$	$0,001^{F,*}$	
	4th day	**1st measurement**	3,53±0,51 $(4)^{A}$	2,40±0,50 $(2)^{B}$	4,13±0,73 $(4)^{A}$	$0,001^{K,*}$
		2nd measurement	6,93±0,69 $(7)^{A}$	4,47±0,57 $(4)^{B}$	6,83±0,75 $(7)^{A}$	$0,001^{K,*}$
		3rd measurement	5,20±0,71 $(5)^{A}$	2,40±0,62 $(2)^{B}$	5,37±0,49 $(5)^{A}$	$0,001^{K,*}$
		^{2}p	$0,001^{F,*}$	$0,001^{F,*}$	$0,001^{F,*}$	

^{K}Kruskal Wallis Test, ^{F}Friedman Test, *p<0.05. Note: Different capital letters in the lines indicate the difference between groups.

Tablo 3

Parameters	Parameters	Mean±SD (Median)	Mean±SD (Median)	Mean±SD (Median)
		US	**BS**	**BSS**
Lactic Acid Level	**1st measurement**	3,66±2,05 $(3,7)^{A}$	3,59±2,26 $(2,7)^{A}$	3,73±1,72 $(3,5)^{A}$
	2nd measurement	12,77±4,67 $(12,1)^{A}$	13,53±4,63 $(12,1)^{A}$	12,89±2,89 $(13)^{A}$
	3rd measurement	7,94±4,10 $(7)^{A}$	5,56±2,54 $(5,2)^{B}$	9,62±2,61 $(9,9)^{A}$
	4th measurement (24th hour)	2,91±1,74 $(2,5)^{A}$	3,07±2,16 $(2,3)^{A}$	3,41±1,98 $(3,3)^{A}$
	^{2}p	$0,001^{F,*}$	$0,001^{F,*}$	$0,001^{F,*}$
Distance	**1st measurement**	13,12±3,18 $(13,1)^{A}$	13,30±3,98 $(12,4)^{A}$	13,15±2,79 $(12,4)^{A}$
	2nd measurement	13,23±3,82 $(12,6)^{A}$	13,73±4,81 $(11,7)^{A}$	13,11±3,60 $(12)^{A}$
	3rd measurement	13,21±3,93 $(12)^{A}$	13,84±5,11 $(12,9)^{A}$	13,08±3,79 $(12,6)^{A}$
	4th measurement	13,28±3,42 $(13)^{A}$	14,10±5,68 $(12,5)^{A}$	13,23±4,40 $(13,6)^{A}$
	^{2}p	$0,914^{F}$	$0,991^{F}$	$0,849^{F}$

^{K}Kruskal Wallis Test, ^{F}Friedman Test, *p<0.05. Note: Different capital letters in the lines indicate the difference between groups.

Table 4

Parameters	Parameters	Mean±SD	Mean±SD	Mean±SD
		US	**BS**	**BSS**
RMSSD	**1st measurement**	25,65±9,51^{A}	24,07±9,75^{A}	27,22±8,5^{A}
	2nd measurement	7,25±2,09^{A}	7,31±2,08^{A}	7,45±2,06^{A}
	3rd measurement	48,84±6,95^{A}	72,17±15,08^{B}	30,78±5,48^{C}
	4th measurement (24th hour)	23,56±10,09^{A}	30,11±10,55^{B}	20,56±10,2^{A}
	^{2}**p**	0,001^{F,*}	0,001^{F,*}	0,001^{F,*}
PNN50	**1st measurement**	7,8±8,86 (3,5)^{A}	6,2±7,03 (4)^{A}	7,57±7,03 (7)
	2nd measurement	0,7±0,65 (1)^{A}	0,8±0,66 (1)^{A}	0,7±0,65 (1)^{A}
	3rd measurement	28,6±9,28 (29,5)^{A}	45,77±14,34 (46,5)^{B}	11,33±5,33 (1
	4th measurement (24th hour)	5,15±5,15 (4)^{A}	11,6±8,66 (10,5)^{B}	3,93±4,86 (2)
	^{2}**p**	0,001^{F,*}	0,001^{F,*}	0,001^{F,*}
LF Power	**1st measurement**	687,79±490,99 (573,4)^{A}	890,08±931,73 (674)^{AB}	1329,69±1068
	2nd measurement	3106,02±529,22 (3153,5)^{A}	2831,11±500,71 (2716,7)^{A}	2997,71±1106
	3rd measurement	2102,65±319,73 (2157,6)^{A}	1246,37±302,85 (1254,8)^{B}	1726,53±1046
	4th measurement (24th hour)	880,08±965,93 (413,9)^{A}	673,54±500,49 (497)^{A}	838,63±708,1
	^{2}**p**	0,001^{F,*}	0,001^{F,*}	0,001^{F,*}
HF Power	**1st measurement**	312,91±216,62 (260,3)^{A}	329,45±395,51 (235,8)^{A}	407,87±347,4
	2nd measurement	39,14±22,83 (35,9)^{A}	36,43±18,22 (33,4)^{A}	56,99±27,89 (
	3rd measurement	296,95±145,25 (286,4)^{A}	532,66±348,75 (460,1)^{B}	68,61±28,26 (
	4th measurement (24th hour)	230,06±183,42 (207,2)^{AB}	384,18±321,83 (327,8)^{B}	159,85±185,3
	^{2}**p**	0,001^{F,*}	0,001^{F,*}	0,001^{F,*}
Lf/Hf Ratio	**1st measurement**	3,5±4,21 (1,7)^{A}	4,17±3,55 (3,4)^{A}	4,25±3,52 (3,
	2nd measurement	113,27±76,47 (87,2)^{A}	95,58±53,21 (76,2)^{A}	68,58±49,48 (
	3rd measurement	9,8±9,93 (6,8)^{A}	2,84±1,15 (2,7)^{B}	31,75±27,67 (
	4th measurement (24th hour)	3,84±2,62 (3,4)^{A}	2,08±1,24 (1,8)^{B}	8,92±6,34 (6,
	^{2}**p**	0,001^{F,*}	0,001^{F,*}	0,001^{F,*}

^{K}Kruskal Wallis Test, ^{F}Friedman Test, *p<0.05. Note: Different capital letters in the lines indicate the difference between groups.

DISCUSSION

In the study, the effect of transcutaneous auricular vagus nerve stimulation applied for 4 days on healthy young individuals on pain, fatigue, blood pressure, heart rate, distance covered, lactic acid level and autonomic nervous system was investigated. Volunteers participating in the study were randomly divided into 3 groups as control, unilateral stimulation and bilateral stimulation, with equal numbers of males and females.

In the study, pain was evaluated with a numerical pain rating scale, fatigue with a numerical fatigue rating scale, heart rate and blood pressure with a digital sphygmomanometer, distance covered with a magnetic exercise bike, lactic acid level with lactate plus, and autonomic nervous system with Polar H10 device. During the study, evaluation was made before and after cycling exercise, before and after vagus nerve stimulation (VSS).

Cook et al. used a numerical pain scale to evaluate pain after cycling exercise in 16 African-American women with a history of parental hypertension (Cook, Jackson, O'connor, & Dishman, 2004). In the study of Jameson and Ring in which they compared the effect of different wattage and cadence of cycling exercise, they evaluated pain with a numerical pain scale (Jameson and Ring, 2000). In the study evaluating the pain caused by the maximum and sub-maximum cycling exercise in the leg muscle, it was compared with the numerical pain scale (Motl, Gliottoni, & Scott, 2007). As in our study, numerical pain scale was used as the evaluation method in the literature.

In another study evaluating pain perception after resistant exercise, after exercise and rest period were compared. In addition to pain, anxiety, body awareness, heart rate, systolic and diastolic blood pressure were also evaluated (Koltyn & Arbogast, 1998). In a study conducted in patients with osteoarthritis, in a study investigating the effect of swimming and cycling exercise on vascular function, pulse, systolic and diastolic blood pressure were also evaluated in addition to blood analysis (Alkatan et al., 2016). Similar to the examples in the literature, in addition to the evaluation methods included in our hypothesis, the participants' pulse, systolic and diastolic blood pressure were measured with a digital blood pressure monitor.

In a study consisting of 18 healthy adult male geneticists, the level of fatigue was regularly questioned during cycling exercise and rest, and a numerical fatigue scale was used for this (Micklewright, St Clair Gibson, Gladwell, & Al Salman, 2017). Another study found that high-intensity cardiorespiratory and strength exercises reduced fatigue and sensory distress in patients with axial spondyloarthritis. Numerical fatigue scale was used to evaluate fatigue in the study (Sveaas, Berg, Fongen, Provan, & Dagfinrud, 2018). In our study, the fatigue level of the participants was evaluated with a numerical fatigue scale.

14 healthy individuals participated in a study investigating the effect of heart rate variability on biofeedback, autonomic function, and functional connectivity of the prefrontal cortex. In the study, the autonomic nervous system was evaluated with the Polar H10 device and the Elite HRV program (Schumann, Köhler, de la Cruz, Brotte, & Bär, 2020). The effect of training load applied at different levels on heart rate variability and running performance was investigated in the study, which included 7 athletes in the Olympic level rugby team. Polar H7 device and Elite HRV program were used to evaluate heart rate variability and autonomic nervous system (Flatt and Howells, 2019). Similar to the examples in the literature, Polar H10 device and Elite HRV program were used in our study.

The lactate scout device was used in the study evaluating the lactate concentration in the blood of 17 Polish sprinters competing in the elite 100 meters category (Kawczyński et al., 2015). 14 people participated in the study investigating the acute effect of peristaltic pneumatic compression. In the study, the repeated anaerobic exercise performance of the participants and the level of lactate in the blood were investigated. The lactate level in the blood was evaluated with the Lactat scout device (Martin, Friedenreich, Borges, & Roberts, 2015). In our study, this device was used to examine the lactate level. In addition, it provided practicality during measurements.

Uthman et al. published a 12-year observation in their study investigating the effectiveness of VSS in patients with epilepsy. 28 people with persistent epilepsy participated in the study. During the treatment, 2 participants could not complete due to traffic accident and cancer. The VSS was performed using a device implanted in the neck. Seizure numbers were noted over the 12-year observation period from the initial moment. The side effects of the application were found to be mild to moderate. The mean seizure frequency was found to decrease by 26% after 1 year, 30% after 5 years, and 52% after 12 years with VSS (Uthman et al., 2004). Rush et al. investigated the effect of VSS on treatment-resistant depression. In this multicenter study, 30 patients who did not benefit from at least two drug trials were included. The application was made with a device implanted in the neck while using the drug. The study, in which the control group was included, lasted 10 weeks. In the study, it was concluded that VSS has as much effects as antidepressants in treatment-resistant depression (Rush et al., 2000). Ten people participated in a pilot study on treatment-resistant anxiety. The patients continued to use their medications for 12 weeks. After the VSS 2-week stimulation adjustment period, the stimulation parameters were fixed for the remaining 8 weeks of the acute study. There was a 50% or greater improvement in the Hamilton anxiety scale for all patients and 25% or greater improvement in the Yale-Brown obsessive-compulsive scale for patients with obsessive-compulsive disorder (George et al., 2008). It has been used in many diseases in the literature, and its use tends to expand as its success increases.

16 people participated in Koltyn et al.'s study evaluating pain perception following aerobic exercise. As an exercise, a bicycle ergometer was used for 30 minutes. A 30-minute rest period was applied after the exercise. In the study, pain was evaluated with a numerical pain scale and an algometer. There was an increase in pain perception after an acute exercise. However, there was a decrease in pain perception during exercise

compared to the rest period. (Koltyn, Birklein, Stefan and Handwerker, 2000). In our study, the second measurement value was higher than the first measurement value every day in all groups. This is due to the increased perception of pain after exercise. This situation is similar to the literature.

Bush et al. conducted an experimental study investigating the effect of transcutaneous VSS on pain perception. It was evaluated with a quantitative sensory test including the tonic heat pain paradigm in 48 healthy volunteers. Each subject attended two experimental sessions in a random order with stimulation or sham stimulation on different days. The stimulated group significantly reduced the level of pain during continuous application of painful heat for 5 minutes compared to the sham group. No related changes in cardiac or respiratory activity or clinically relevant adverse effects were observed during administration (Busch et al. 2013). Ten healthy volunteers participated in an experimental study investigating the effect of VSS applied from the left cervical region on pain. Pain is created by heat, pressure, and short-term pulsing. Pain was evaluated with a visual analog scale. As a result of the study, it was found that VSS was effective in reducing pain in humans (Kirchner et al., 2000). In all groups, the 3rd measurement value is lower than the 2nd measurement value. This shows that pain decreased in all groups. However, the values in the TVSS and control groups are higher than those in the DVSS group. In other words, VSS is effective in relieving pain. However, when we compare the control and TVSS groups, there is no difference in the effect on pain.

The acute effects of two types of aerobic exercise on maximum strength and endurance were investigated. Eight men with a high level of physical activity participated. It has a randomized design in which all subjects complete both control and experimental conditions. Each session was held 1 week apart. The study revealed that both aerobic and strength exercises produced significant peripheral fatigue in the same muscle group (De Souza et al., 2007). In a study investigating the acute effect of aerobic exercise on mood, 32 female students aged 18 to 23 participated in a single-session experiment in which they performed two 8-minute high-intensity exercise trials and two 8-minute low-intensity exercise trials. Fatigue level was evaluated with borg fatigue scale. In general, they found that high-intensity exercise leads to an increase in tension/anxiety and fatigue (Steptoe and Cox, 1988). In our study, the second measurement values of the participants in all groups were higher than the first measurement values. As in the literature, we have observed that exercise acutely increases fatigue.

A study was conducted investigating the effect of noninvasive VSS on fatigue and immune responses in patients with primary Sjögren's syndrome. 15 female subjects participated in the study. The VSS was applied from the cervical region in a non-invasive manner, twice daily over a 26-day period. Fatigue-related data were collected on days 7 and 28 by fatigue profile index and visual analog scale. They found that the vagus nerve may play a role in the regulation of fatigue and immune responses in patients with primary Sjögren's syndrome and may reduce the clinical symptoms of VSS related to fatigue and sleep problems (Tarn, Legg, Mitchell, Simon, & Ng, 2019). A randomized controlled clinical trial was conducted investigating the effect of auricular VSS for insomnia. 72 subjects from three different hospitals participated. Participants were randomly divided into 2 groups as control and stimulation. Fatigue level was evaluated with the Flinders fatigue scale. It was concluded that VSS relieves fatigue, improves participants' quality of life and other accompanying symptoms such as depression and anxiety (Jiao et al., 2020). Similar to the literature, as in our study, fatigue scores obtained from the control group were higher than the TVSS and DVSS groups. This shows that VSS is effective in reducing fatigue. However, the superiority of the single and double ear application over each other was not observed.

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