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Clinical studies on the electric automatic massage therapy for recovery of acute sports fatigue

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Abstract.
BACKGROUND: Acute sports fatigue impairs athletes' performance and causes other health issues; therefore, an effective method of relieving acute sports fatigue is being researched. Objective: The present study was envisaged to evaluate the effect of electric auto-massage therapy and proprioceptive neuromuscular facilitated (PNF) stretching method on the recovery of acute exercise fatigue using the heart rate variability-based multi-physiological index and RPE scale, and to explore the underlying principle and mechanism.
METHOD: Sixty volunteers were divided into the stretching group, massage group and control group (20 subjects each) using the complete randomization method. The massage group chose the kneading, pressing, tapping and patting techniques using the intelligent massage chair to intervene on the volunteers, the stretching group chose the PNF stretching method to intervene on the volunteers, while the control group did not adopt any of these techniques. The Rating Of Perceived Exertion (RPE) score, heart rate (HR), grip strength, skin electrical activity, heart rate variability (HRV) and blood oxygen saturation (SpO_2) of the three groups were recorded before and after the intervention.
RESULTS: Before the intervention, there was no statistically significant difference between the values of heart rate variability (HRV) in the three groups ($P > 0.05$), while after the intervention, there was a statistically significant difference between the values of heart rate variability – low frequency/high frequency (HRV (LF/HF)) and HRV (HF) in the three groups as: HRV (HF): $\eta^2_H = 0.10$; $P = 0.022$; HRV (LF/HF): $\eta^2_H = 0.44$; $P = 0.001$. The results indicated that the different intervention methods presented substantial effects on the values of HRV (HF) and HRV (LF/HF) in the volunteers. The HRV (HF) values of massage group, stretching group and control group were compared, and the difference between the massage group and control group was statistically significant ($P = 0.019$). Further, the HRV (HF) values of massage group rose more significantly than control group after the intervention, and the difference between HRV (HF) values of massage group and stretching group was not statistically significant. When comparing the HRV (LF/HF) values of massage group, stretching group and control group, the differences between the massage group and stretching group and control group were statistically significant ($P = 0.001$, $P < 0.05$), and it was observed that the HRV (LF/HF) values of massage group decreased more significantly than those of stretching group and control group after the intervention. The difference in HRV (LF) values between the three groups after the intervention was not statistically significant ($P > 0.05$).
CONCLUSION: 1. It was observed that the electric automatic massage therapy played a vital role in the rapid relief of exercise fatigue by soothing and regulating the human phototropic system, reducing vagal tone, and accelerating the excretion of metabolites; while PNF stretching relieved the exercise fatigue by providing physical and verbal communication to transfer the perception of fatigue, and by promoting the excretion of metabolites through muscle isometric contraction. 2. The effect of electric auto-massage therapy was marginally stronger than the commonly used PNF stretching exercise method.

Keywords: Acute exercise fatigue, heart rate variability, electro-auto massage therapy

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1. Introduction

Acute exercise fatigue manifests with a decrease in the maximum performance of the organism machinery due to heavy exercise affecting the muscle cell forces, central nervous motor drive, and muscle performance that cannot be maintained at a specific level, or the organs cannot maintain the intended intensity of exercise [1]. Fatigue that occurs after performing acute exercise includes both somatic and mental fatigue [3], and this fatigue may be due to a combination of factors such as the depletion of large amounts of energy substances, the accumulation of metabolites, and the increase in free radicals due to the oxidation of body cells [4]. After acute exercise, if not relieved in time, it may not only affect athletes' performance and sports injuries [6], but also cause other health problems due to the fatigue caused by the combination of multiple factors [8]. Fatigue not only leads to health problems, but also leads to occupational accidents due to the different occupations of the fatigued groups [12]. Therefore, the search of the means to effectively relieve the acute sports fatigue is a key research area in sports medicine.

Tui Na, also known as massage, is one of the external therapies of traditional Chinese medicine that mainly utilizes specific techniques on the upper extremities and applies mechanical stimulation to the treatment area or specific acupoints with different combinations of techniques to harmonize the Yin and Yang, relax the tendons and channels, regulate the tendons and rectify them, and activate blood stasis [15]. In modern research on the relief of motor fatigue by *tui na*, studies have concluded that the combination of mechanical stimulation and biological effects produced by the contact between *tui na* hands and skin can increase the blood flow, reduce the muscle tone and nerve excitability, and thus relieve fatigue [16]. With the progress of science and technology, the process of mechanical automation has gradually advanced, and the electric automatic massage chair developed from the theory of traditional medical *tui na* has been gradually developed and applied to medical and healthcare fields, and the electric automatic massage chair has realized the automation, intelligence and functionalization of *tui na* manipulation, which greatly reduces the labour cost and breaks the time and space limitation [17]. Compared with the traditional *tui na*, the electric automatic massage therapy has shown effectiveness in pain control, patient satisfaction and improvement in the quality of life, and is indeed superior in terms of the cost effectiveness [18].

The proprioceptive neuromuscular facilitated (PNF) stretching method [19], is a technique that uses the motor-sensory and postural sensory stimuli to enhance the relevant neural responses based on the neurophysiological phenomena such as the detrusor reflex and reflex relaxation of antagonistic muscles, as well as *in vivo* inhibition and cross-inhibition mechanisms. It promotes the contraction of the corresponding muscles and improves muscle flexibility, especially for enhancing the active and passive range of motion that, thereby optimizing the motor performance and rehabilitation. Because of its ability to effectively improve the muscle performance, improve joint range of motion and relieve muscle fatigue significantly, in recent years it has been widely used in the training and relaxation process of athletes.

In this pursuit, the present study objectively evaluated the effect of different intervention methods on acute exercise fatigue by intervening in different ways on volunteers with acute exercise fatigue based on heart rate (HR), heart rate variability (HRV), skin resistance, grip strength of both hands, blood oxygen saturation (SpO_2) and other physiological indicators. The effect of different interventions on acute exercise fatigue was objectively evaluated based on physiological indicators such as heart rate, HRV, SCL, handgrip strength and SpO_2.

2. Methods

The study employed a randomized controlled trial with a completely randomized design. Sixty volunteers of the dragon boat team of the Shanghai University of Traditional Chinese Medicine from November

2021 to January 2022 were selected, and the volunteers were divided into stretching group, massage group and control group (20 subjects each) according to 1:1:1 by using completely randomized grouping.

3. Participants

3.1. Diagnostic criteria of acute sports fatigue

In this study, the fatigue intensity was assessed on the 6–20 rating scale (ratings of perceived exertion, RPE) of Swedish scholar Borg [21]. Its scoring scale is as follows:

> 6 points: No exertion at all; 7–8 points: Extremely light; 9–10 points: Very light; 11–12 points: Light; 13–14 points: Somewhat hard; 15–16 points: Hard; 17–18 points: Very hard; 19 points: Extremely hard; 20 points: Maximal exertion. A score of RPE $\geqslant 17$ was classified as an acute motor fatigue state [22].

3.2. Inclusion criteria

(1) Athletes of the dragon boat team of the Shanghai University of Traditional Chinese Medicine, aged 18–24 years, in good health, with no abnormalities found in the routine physical examination.
(2) Subjective fatigue rating of RPE $\geqslant 18$ immediately after training.
(3) Those with extreme fatigue immediately after the training, and those who had the above criteria were included in the experiment.

3.3. Exclusion criteria

(1) Those with a subjective fatigue RPE of < 18 points immediately after the end of heavy exercise training.
(2) Those who failed to achieve extreme fatigue in the symptom assessment after the end of heavy exercise training.
(3) Those who had recent sports injuries and were not been able to resume normal training and those who did not complete the treatment according to the experimental requirements.

3.4. Discontinuation criteria

(1) During the experiment, if the subject's compliance was poor that affected the evaluation of effectiveness and safety.
(2) In the course of the experiment, if the subject withdrew himself for various other reasons before the end of the treatment.

4. Intervention

4.1. Experimental instruments

The fatigue detection and assessment system was based on the theory of Chinese medicine Tibetan elephant by the Shanghai University of Traditional Chinese Medicine and Shanghai Rongtai Health Technology Co.RT8900 massage chair was procured from the Shanghai Rongtai Health Science and Technology Co.

4.2. Test method

(1) Blank control group: referred to as the control group. The subjects sat quietly in the RT8900 space capsule massage chair rested 30 min, but the chair was not operated.
(2) Massage group: the RT8900 space capsule massage chair was operated for volunteers to intervene. The massage chair was in the "work decompression" mode during the operation.
"Work decompression" mode refers to the use of three-axis linkage 3D three-dimensional massage movement, massage head was multi-directional independent expansion, the longest up to 8 cm, achieved full stretching of the body, provided back super-long SL-type guide from the neck straight to the waist and hip, covering the entire back; plantar three rows of roller scraping design fully stimulated to all points of the foot, and the 3D Flexible airbags achieved the whole body kneading pressure. The whole process of a variety of massage techniques overlapped alternately, using rhythmic massage, rapid stretching of the whole body muscles, and relieved tight muscles to achieve rapid relaxation of the whole body.
(3) PNF stretching group refers to the stretching group. Sitting position, supine position, prone position; sitting position: stretching the upper trapezius, pectoralis major; supine position: stretching the calf triceps, hamstrings, gluteus maximus; prone position: stretching the rectus femoris. After ten minutes of stretching, an additional twenty minutes of rest was employed.

5. Observation index

The observation index was collected before and after the intervention.

5.1. Subjective indicators

The Swedish scholar Borg's 6–20 grading (ratings of perceived exertion, RPE) scale was used to score the subjective perception of fatigue, and the RPE score was $\geqslant 18$.

5.2. Physiological indicators

The 'Human Fatigue Detection and Evaluation System' developed by the Institute of Traditional Chinese Medicine Engineering, Shanghai University of Traditional Chinese Medicine was used to detect the skin resistance SCL, HRV and SPO_2. The recording time was 2 min, and the test site was Shaochong point and the grip strength of both hands.

6. Estimation of sample size

The study used a completely randomized design, calculated by F-test and one-way ANOVA with SPSS 15.0 software, based on previously reported heart rate variability – low frequency/high frequency [HRV (lf/hf)] values, and after accounting for a 20% shedding rate, the trial required 60 study subjects (20 in each of the three groups) to obtain a 90% certainty at a significant level of $\alpha = 0.05$ (one- and two-sided) (Power $= 1 - \beta$) to detect a statistical difference in clinical outcome between the three groups.

7. Statistical analysis

SPSS 24.0 software was used to analyze the data, and the measures were expressed as mean and

Table 1
General information

Group	Cases	Age	Gender		BMI	Basal heart	Basal grip strength	
			Male	Female			Left hand	Right hand
Stretching group	20	20.65 ± 0.69	12	8	21.24 ± 0.54	69.60 ± 0.51	34.05 ± 2.10	36.20 ± 2.21
Massage group	20	19.81 ± 0.51	9	12	21.22 ± 0.50	70.52 ± 1.58	30.72 ± 2.25	32.49 ± 2.20
Control group	20	20.15 ± 0.44	10	10	21.53 ± 0.69	70.45 ± 2.03	30.29 ± 2.55	33.10 ± 2.56
$F/H/\chi^2$		0.550	1.21		0.091	0.082	0.80	0.73
P		0.574	0.55		0.913	0.921	0.46	0.49

Table 2
ANOVA results of the RPE rating scale for the 3 groups ($\bar{\chi} \pm S$)

Group	Pre-intervention	Pro-intervention	Difference
Stretching group	18.85 ± 0.18	8.85 ± 0.24	10.00 ± 1.21
Massage group	18.76 ± 0.19	7.67 ± 0.232	11.10 ± 1.04
Control group	18.60 ± 0.22	9.50 ± 0.45	9.10 ± 1.89
F	0.395	8.836	
P	0.675	0.001	
η^2	0.01	0.23	

standard deviation. One-way ANOVA was used for comparing between the groups for measures that conformed to a normal distribution with unity of variance, and the effect value (η^2) = sum of squares between groups (SSbetween)/total sum of squares (SStotal). For data with non-normal normal distribution or unity of variance, the rank sum test for comparison of multiple independent samples was used, and the effect value (η^2_H) = $(H - k + 1)/(n - k)$, with η^2 at 0.01, 0.06, and 0.14 represented small, medium, and large effect values, respectively. $p < 0.05$ indicated that the difference was statistically significant.

8. Results

8.1. General information

The age, gender, BMI, basal heart rate, and left and right hand grip strength values of the volunteers in the three groups were compared, and the differences were not statistically significant ($P > 0.05$) and were comparable, as detailed in Table 1. The study protocol was approved by the Ethics Committee of Shuguang Hospital, Shanghai University of Traditional Chinese Medicine (Approval number: 2020-886-95-01).

8.2. RPE scores

Before the intervention, there was no statistically significant difference between the RPE scores of the 3 groups ($\eta^2 = 0.01$; $P = 0.675$), while after the intervention there was a statistically significant difference between the RPE scores of the 3 groups ($\eta^2 = 0.23$; $P = 0.001$). It can be concluded that the 3 intervention methods presented an effect on the RPE scores of the volunteers.

In comparing the RPE scores of the massage group with the stretching group and the control group, the difference in the massage group with the stretching group was statistically significant ($P = 0.012$); the difference in the massage group with the control group was statistically significant ($P = 0.001$). After the intervention, the RPE scores of the massage group decreased more significantly than those of the stretching group and the control group, as shown in Table 2.

Table 3
ANOVA results of the HR rating scale for the 3 groups ($\chi \pm S$)

Group	Pre-intervention	Pro-intervention	Difference
Stretching group	183.85 ± 8.32	83.25 ± 8.61	100.60 ± 12.73
Massage group	183.19 ± 8.06	74.24 ± 7.675	108.95 ± 9.28
Control group	175.55 ± 13.47	89.10 ± 12.47	86.45 ± 24.43
H	3.347	18.89	
P	0.188	0.001	
η_H^2	0.02	0.29	

Table 4
ANOVA results of grip strength values for the 3 groups ($\bar{\chi} \pm S$)

Group	Left hand		Right hand		Difference	
	Pre-intervention	Pro-intervention	Pre-intervention	Pro-intervention	Left hand	Right hand
Stretching group	2985 ± 7.85	31.07 ± 7.97	31.83 ± 8.04	33.08 ± 7.96	−1.22 ± 3.38	−1.26 ± 3.25
Massage group	26.79 ± 10.88	28.30 ± 9.80	28.85 ± 9.80	28.95 ± 9.50	−1.50 ± 3.96	−0.11 ± 4.33
Control group	25.65 ± 9.13	29.68 ± 11.1	27.45 ± 9.30	31.54 ± 10.78	−4.03 ± 4.61	−4.09 ± 3.68
F	1.070	0.417	1.161	0.996		
P	0.350	0.661	0.320	0.376		
η^2	0.04	0.01	0.04	0.03		

8.3. Heart rate (HR)

Before the intervention, there was no statistically significant difference between the HR scores of the three groups ($\eta_H^2 = 0.02$; $P = 0.188$, $P > 0.05$), while after the intervention, there was a statistically significant difference between the HRs of the three groups ($\eta_H^2 = 0.29$; $P = 0.001$, $P < 0.05$), and it can be concluded that the different intervention methods had an effect on the HR values of the volunteers.

In the comparison of the HR values of the massage group with those of the stretching group and the control group, the difference in the massage group and the stretching group was statistically significant ($P = 0.049$), and that of the massage group and the control group was also statistically significant ($P = 0.002$). After the intervention, the HR values of the massage group decreased more significantly than those of the stretching group and the control group, and the details are shown in Table 3.

8.4. Grip strength

Before the intervention, there was no statistically significant difference between the grip strength values of the 3 groups (left hand: $\eta^2 = 0.04$; $P = 0.350$; right hand: $\eta^2 = 0.04$; $P = 0.320$, $P > 0.05$). Also, after the intervention, there was no statistically significant difference in the grip strength between the 3 groups (left hand: $\eta^2 = 0.01$; $P = 0.661$; right hand: $\eta^2 = 0.03$; $P = 0.376$, $P > 0.05$). The results indicated that the different intervention methods had no statistically significant effect on the grip strength values of the left and right hands of the volunteers (for details, please refer to Table 4).

8.5. Skin resistance (SCL)

Before the intervention, there was no statistically significant difference between the values of SCL in the 3 groups ($P > 0.05$). After the intervention, the differences in SCL (max), SCL (v) and SCL (mean) among the 3 groups were statistically significant ($P < 0.05$). SCLl (max): $\eta_H^2 = 0.13$; $P = 0.010$; SCL (v): $\eta_H^2 = 0.20$; $P = 0.001$; SCL (mean): $\eta_H^2 = 0.08$; $P = 0.038$. The results indicated that the different

Table 5
ANOVA results of SCL values for the 3 groups ($\bar{\chi} \pm S$)

Group Indicators		Stretching group	Massage group	Control group	H	P	η^2_H
SCL (max)	Pre-intervention	29.97 ± 18.59	27.17 ± 10.44	27.03 ± 11.60	3.255	0.196	0.02
	Pro-intervention	38.58 ± 13.82	39.88 ± 12.47	29.89 ± 15.56	9.251	0.010	0.13
SCL (min)	Pre-intervention	22.81 ± 9.23	22.69 ± 8.58	22.83 ± 8.40	0.094	0.954	0.03
	Pro-intervention	29.44 ± 12.59	29.76 ± 10.69	25.15 ± 10.26	2.189	0.335	0.01
SCL (v)	Pre-intervention	5.56 ± 4.29	4.46 ± 3.30	4.20 ± 4.10	2.280	0.320	0.01
	Pro-intervention	9.14 ± 6.15	10.13 ± 6.00	5.23 ± 6.58	13.375	0.001	0.20
SCL (mean)	Pre-intervention	25.38 ± 10.73	24.98 ± 9.19	24.49 ± 9.51	0.082	0.960	0.03
	Pro-intervention	33.76 ± 11.82	33.90 ± 10.64	27.18 ± 11.82	6.565	0.038	0.08

intervention methods exhibited a statistically significant effect on the SCL (max), SCL (v) and SCL (mean) values of volunteers.

When the SCL (max) and SCL (v) values of the massage group were compared with those of the stretch and control group, the differences between the massage and control groups were statistically significant: SCL (max) value, $P = 0.016$; SCL (v) value, $P = 0.002$. After the intervention, the SCL (max) and SCL (v) values increased more significantly than those of the control group, and the differences between the SCL (max) and SCL (v) values of the massage group and the stretching group were not statistically significant ($P > 0.05$). The differences in SCL (max) and SCL (v) in the stretching group was statistically significant compared to the control group: the SCL (max) value, $P = 0.042$; and the SCL (v) value, $P = 0.017$, and increased more significantly than in the control group.

When the SCL (mean) values of the massage group were compared individually with those of the stretching group and the control group, none of the differences were statistically significant ($P > 0.05$), and the intervention method of the massage group could not present a statistically significant effect on SCL (mean) than that of the control and stretching groups. The difference in SCL (mean) between the control and stretching groups was statistically significant ($P = 0.019$), and it can be considered that the increase in SCL (mean) values after the intervention was more significant in the PNF stretching method than in the control group.

The difference in the SCL (min) values between the 3 groups after the intervention was not statistically significant ($P > 0.05$). The results indicated that the different intervention methods had no statistically significant effect on the SCL (min) values of the volunteers (for details, please refer to Table 5).

8.6. Heart rate variability (HRV)

Before the intervention, there was no statistically significant difference between the values of HRV in the 3 groups ($P > 0.05$), while after the intervention, there was a statistically significant difference between the values of HRV (HF) and HRV (LF/HF) in the three groups. HRV (HF): $\eta^2_H = 0.10$; $P = 0.022$; HRV (LF/HF): $\eta^2_H = 0.44$; $P = 0.001$. It can be concluded that the different intervention methods exhibited a statistically significant effect on the values of HRV (HF) and HRV (LF/HF) in the volunteers. The HRV (HF), HRV (LF/HF) values of volunteers showed a significant effect.

In the comparison of the HRV (HF) values, the difference in the massage group and control group was statistically significant ($P = 0.019$), it can be considered that after the intervention, the HRV (HF) values of massage group rose more significantly than the control group. The difference between the HRV (HF) values of massage group and stretching group was not statistically significant, and there was no significant effect of the two intervention methods on HRV (HF) values here. On comparing the HRV (LF/HF) values of the different groups, the differences between the massage group and the stretching

Table 6
ANOVA results of HRV values of the 3 groups ($\bar{\chi} \pm S$)

Group / Indicators		Stretching group	Massage group	Control group	H	P	η_H^2
HRV (HF)	Pre-intervention	12.25 ± 8.31	11.39 ± 5.66	8.60 ± 7.58	2.566	0.277	0.01
	Pro-intervention	15.25 ± 7.14	15.18 ± 5.46	12.89 ± 5.51	7.612	0.022	0.10
HRV (LF)	Pre-intervention	8.15 ± 4.94	5.75 ± 3.36	6.30 ± 3.64	2.751	0.253	0.01
	Pro-intervention	5.54 ± 3.37	4.26 ± 2.37	5.22 ± 3.30	1.207	0.547	0.01
HRV (LF/HF)	Pre-intervention	0.52 ± 0.10	0.48 ± 0.10	0.51 ± 0.10	2.070	0.355	0.01
	Pro-intervention	0.46 ± 0.09	0.29 ± 0.13	0.51 ± 0.09	27.48	0.001	0.44

Table 7
ANOVA results for the 3 groups of SPO_2 ($\chi \pm S$)

Group	SPO_2 (min)		SPO_2 (mean)	
	Pre-intervention	Pro-intervention	Pre-intervention	Pro-intervention
Stretching group	97.91 ± 1.67	98.11 ± 1.11	99.20 ± 0.84	99.30 ± 0.57
Massage group	98.53 ± 0.91	99.07 ± 0.71	99.33 ± 0.70	99.60 ± 0.47
Control group	98.63 ± 0.73	98.98 ± 0.46	99.20 ± 0.60	99.30 ± 0.51
F	2.265	1.122	13.72	6.77
P	0.322	0.571	0.001	0.034
η^2	0.07	0.23	0.01	0.08

group and the control group were statistically significant ($P = 0.001$, $P < 0.05$), respectively. It was observed that the HRV (LF/HF) values of the massage group decreased more significantly than those of the stretching group and the control group after the intervention.

The difference in the HRV (LF) values between the three groups after the intervention was not statistically significant ($P > 0.05$), and the results indicated that the different intervention methods did not present a statistically significant effect on the HRV (LF) values of the volunteers (Table 6).

8.7. Blood oxygen saturation (SPO_2)

Before the intervention, the differences in $SP0_2$ (min) and SPO_2 (mean) scores of the three groups were not statistically significant ($P > 0.05$). After the intervention, the differences in $SP0_2$ (min) of the three groups were statistically significant ($\eta^2 = 0.23$, $P = 0.001$, $P < 0.05$), and it can be concluded that different intervention methods had an effect on the SPO2 values of volunteers.

The differences between the massage group and the stretching group were statistically significant ($P =$ 0.001), and after the intervention, the $SP0_2$ (min) values of the massage group rose more significantly than that of the stretching group. The differences between the massage group and the control group were not statistically significant ($P > 0.05$). The difference of SPO_2 (min) in the stretching group was statistically significant ($P = 0.001$) compared to the control group, and the rise was more significant than the control group (Table 7).

9. Discussion

9.1. Effect of different recovery modalities on RPE

The subjective rating scale of the physical perception (RPE) [21], which is used to determine the intensity of the exercise prescription, is one of the most widely used and relatively more accurate method to subjectively assess the exercise-related fatigue by subjectively evaluating the level of fatigue and the corresponding exercise intensity during exercise. The physical and psychological load caused by acute exercise can lead to an increase in the perception of fatigue, and the RPE scale is usually used to assess the physical tension in the assessment of fatigue.

In this study, the subjective physical sensation scale was used to assess the fatigue level before and after the intervention of the 3 methods. The RPE scores of the massage group were compared with the stretching group and the control group, respectively, and the differences were found to be statistically significant. The RPE scores of the massage group decreased more significantly than those of the stretching group and the control group. Therefore, it can be concluded that massage therapy could significantly reduce the RPE scores compared to the PNF stretching method and rest alone. Electric automatic massage therapy using the simulation of the massage techniques on the body manipulation stimulates the phytonervous system to offer a relaxation effect. In the PNF stretching method, because the subjects cooperate to complete through physical contact, language and eye contact, it transfers the discomfort concentrated in the muscle, thereby reducing their own perceptual response, and employing a psychological regulation.

9.2. Effects of different recovery methods on HR and HRV

Although the subjective assessment method can reflect the degree of fatigue to a certain extent, a more accurate and convenient measurement method relies on the monitoring of the objective physiological indicators [23], which include the heart rate, heart rate variability, skin resistance, and oxygen saturation. Heart rate and heart rate variability are the indirect indicators of the autonomic nervous system tone *in vivo*, where changes in the heart rate can reflect the exercise intensity to some extent due to changes in an autonomic activity affecting the cardiac autoregulation. Heart rate recovery after exercise is influenced by the interactive and coordinated effects of sympathetic and parasympathetic nerves [24]. It is known that the cardiac autonomic tone can be indirectly assessed by measuring the heart rate variability (HRV) at rest, during and after exercise to monitor the fatigue [25], wherein the HRV frequency domain indicators can reflect the degree of sympathetic and parasympathetic activity. The low frequency (LF) peaks reflect the sympathetic and parasympathetic regulation, and high frequency (HF) peaks reflect the vagal nerve activity. The LF/HF ratio reflects the autonomic balanced state, and the above frequency domain indexes are more sensitive for detecting the exercise fatigue state [24]. A related study [27] showed that the sympathetic nerve activity was significantly active and the parasympathetic nerve activity was weakened in the fatigue state, and the corresponding frequency domain indexes of HRV were lower in HF and higher in LF and LF/HF ratio [28].

The results of this study showed that after different intervention methods, the differences in the HR, HF, and HF/LF values of the 3 groups were statistically significant, and the HR and HF/LF values of the massage group decreased more significantly than that of the stretching group and the control group. The HF values increased more significantly than those of the control group, while the differences were not statistically significant than those of the stretching group. The differences in LF values of the three groups after intervention were not statistically significant. Although the differences between the LF values of the 3 groups after the intervention were not statistically significant ($P > 0.05$), the ratio decreased after the intervention compared to that before the intervention. The changes in the HR and HRV frequency domain indexes in the 3 groups after the intervention were consistent with the previous studies, with the most significant changes exhibited by the massage group. The changes in HRV frequency domain indexes indicated a shift from the sympathetic to parasympathetic activity, and the increase in vagal nerve activity resulted in slowing of the heart rate due to the vagal branches covering the heart. This could be due to the electric automatic massage chair massage of the back of the bladder meridian. The bladder meridian and the modern medicine sympathetic and vagus nerves are closely related. Modern medicine believes that the sympathetic nerves regulate the function of internal organs by the visceral efferent fibres of the spinal nerves, etc., which form the sympathetic trunk on both sides of the spine, corresponding to the five internal organs, and regulate the function of internal organs. This has the same role as the dorsal acupoints distributed on both sides of the spine by the bladder meridian [29]. The acupoints are the response points of the diseases on the surface of the body, and the response points of the five viscera and six internal organs on the surface of the body are located in the dorsal acupoints on both sides of the Governor's vein. Thus, the corresponding internal organ functions are adjusted, when the dorsal acupoints are benignly stimulated.

9.3. Effect of different recovery methods on SCL values

The increased sympathetic nerve activity in the fatigue state leads to the increased activity of subcutaneous sweat glands, causing dermal electrical changes, and studies have shown that dermal electrical signals can reflect the fatigue state of the body. It has the characteristics of a non-invasive, efficient and convenient indicator, so it can be used as a physiological indicator to monitor the fatigue [30]. When sympathetic excitation occurs, it accordingly leads to an increase in the amount of sweat secreted by the sweat glands, which leads to wetting of the skin due to sweat. This in turn leads to a decrease in the epidermal resistance and an increase in skin conductance [32].

The experimental results showed statistically significant differences in SCL (max), SCL (v), and SCL (mean) in the 3 groups, in which the SCL (max) and SCL (v) values of the massage group and the stretching group increased more significantly than those of the control group, but the differences between the massage and stretching groups were not statistically significant. The SCL (mean) values of the massage group and the stretching group and the control group, were not statistically significant ($P > 0.05$), and the stretching method of SCL (mean) values increased more significantly than the control group. It can be seen that both the electric automatic massage therapy and the PNF stretching method exhibited a significant effect on the SCL values, but the sensitivity of each index was different, and overall the massage therapy was found to be the most significant, followed by the PNF stretching method. On the one hand, the electric auto-massage can relieve the emotional stimulation after acute exercise by regulating the emotions. Since the secretion activity of palmar sweat glands is constant in response to the emotional stimulation, the skin electrical activity also changes with the change of emotion. On the other hand, because the electric auto-massage can regulate the sympathetic excitability, and the sympathetic nerve controls the body sweating response when the sympathetic excitability is relieved at the same time, the activity of the sweat gland secretion decreases. The effect of PNF on SCL may be due to the active contraction of muscles, which increases the local blood flow of muscles and accelerates the discharge of sweat lactate. This affects the sweating rate, which is due to the significant positive correlation between sweating rate and sweat lactate, and the change of SCL.

9.4. Effect of different recovery modalities on grip strength

When fatigue occurs after an exercise, there is a decrease in the strength of the muscles or muscle groups involved in the work, which is due to a large number of neurotransmitters deprived of muscle strength after high-intensity exercise. As a result, measuring the grip strength can reflect the intensity of the fatigue to some extent. The experimental results showed that the grip strength values of the 3 groups were not significant before and after the intervention, but the grip strength values before the intervention were improved to some extent, indicating that different intervention methods can alleviate muscle strength to some extent. The difference in the grip strength of the left hand in the stretching group was -1.22 ± 3.38, the massage group was -1.50 ± 3.96, and the control group was -4.03 ± 4.61; the difference in grip strength of the right hand in the stretching group was -1.26 ± 3.25, the massage group was -0.11 ± 4.33, and the control group was -4.09 ± 3.68. It can be seen that the effect of the control group on the recovery of muscle strength was better than that of the massage. The recovery of muscle strength of the left hand was better in the massage group than in the stretch group, and the recovery of muscle strength of the right hand was better in the stretch group than in the massage group. The reason for this difference could be the different dominant hands of individuals, and also because when rowing exercise is performed, the rectus femoris and oblique muscles are the active muscle groups for rowing action, so measuring the grip strength of both hands will lead to some differences.

9.5. *Effect of different recovery methods on blood oxygen saturation*

After a certain intensity of exercise, the sympathetic excitation of the body leads to an increase in the basal metabolism and leads to a large consumption of oxygen stored in the body. When there is an imbalance between the oxygen consumption and oxygen uptake, the total oxygen content of the body decreases, which accelerates the metabolism of the body and increases the fatigue of the body [34]. A number of studies [36], have also shown that changes in the fatigue can cause changes in the blood oxygen saturation, so monitoring the changes in blood oxygen saturation can reflect the real-time fatigue level of the body.

The experimental results showed that after the intervention of the 3 groups, the differences between the $SP0_2$ (min) and SPO_2 (mean) in the 3 groups were statistically significant ($P < 0.05$). The SPO_2 (min) in the massage group was significantly higher than that in the stretching group, and the SPO_2 (mean) in the massage group was significantly higher than that in the control group. *Tui na* has the function of moving *qi* and activating blood flow, promoting blood circulation, improving local microcirculation, and promoting the metabolism of the organism. During stretching, the contraction of the isometric muscle produces a strong stimulation to the muscle. The stimulation signal is transmitted to the central nerve through the tendon shuttle, which reflexively makes the muscle relaxed, while the active muscle contraction will increase the local blood flow, thus accelerating the elimination of metabolites.

10. Conclusion

The present study investigated the effect of electric auto-massage therapy and PNF stretching method on the recovery of acute exercise fatigue using the heart rate variability-based multi-physiological index and RPE scale, and to explore the underlying mechanisms. The results indicated that both the electric auto-massage therapy and the PNF stretching method could alleviate the fatigue caused due to the acute exercise to a certain extent. Electric auto-massage therapy significantly improved RPE, HR, HRV (HF), HRV (HF/LF), SCL (max), SCL (v), and SPO_2, which may be due to the effect of reducing sympathetic excitability and enhancing parasympathetic activity to relieve fatigue. PNF stretching improved SCL (max), SCL (v), SCL (mean), and SPO_2 (min) values, which could be attributed to the *in vivo* inhibition and cross-inhibition mechanism of PNF stretching. PNF stretching causes neural inhibition, which causes motor neurons in the excited state to stop releasing impulses back to the subthreshold excited state, causing muscles to relax reflexively. Overall, the effect of electro-automassage therapy on the relief of acute motor fatigue was stronger than that of PNF stretching method, so it can be considered that electro-automassage therapy can be used as a measure to relieve acute motor fatigue and acute exercise fatigue. This study provides a clinical basis for the relief of acute sports fatigue using electric auto-massage therapy and provides a more convenient, efficient, non-invasive detection method and a means to relieve the acute sports fatigue. However, there are some shortcomings in this study like a small sample size and a short intervention time, which could only verify the immediate relief effect of the electric automatic massage therapy against the acute sports fatigue. The influence of the electric automatic massage techniques on the physiological temperature of the body and the different effects of different simulation procedures on the body was ignored in the intervention process. These deficiencies still need a further study, so as to understand the detailed underlying mechanisms of countering the motor and acute sports fatigue.

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Conflict of interest

None to report.

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