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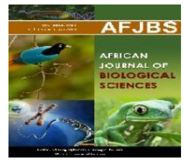

Research Paper Open Access

Investigating the Biological Impact of a Hot Circle EMS Massage Belt on Abdominal Muscle Exercises in Healthy Women

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Abstract

This study aimed to explore the impact of integrating a Hot Circle Electrical Muscle Stimulation (EMS) massage belt (SPCARE Inc., South Korea) into abdominal muscle strengthening exercises among young women, focusing on body composition, metabolic rate, and abdominal muscle fatigue. Twenty-two healthy female participants were randomly assigned to either the EMS massage belt group or the placebo group. Both groups followed a four-week regimen of five abdominal exercises three times a week. Various outcome measures, including body composition indicators (body fat, weight, body mass index, waist circumference), muscle fatigue, muscle temperature, respiratory exchange rate, metabolic rate, and heart rate, were assessed. Data analysis employed the Wilcoxon-signed-rank test for within-group changes over time and the Mann–Whitney U-test for between-group comparisons. Results demonstrated significant reductions in body fat, body mass index, and waist circumference, alongside increases in resting metabolic rate, respiratory exchange rate, muscle fatigue threshold, and muscle temperature ($p<0.05$). Comparable changes occurred in the placebo group, though not in waist circumference, muscle fatigue, and muscle temperature ($p>0.05$). Furthermore, when comparing the EMS group to the placebo group, the former exhibited noteworthy reductions in waist circumference and increases in muscle fatigue threshold and muscle temperature ($p<0.05$). In conclusion, integrating an EMS massage belt with abdominal exercises proved beneficial, showing reduced body fat and enhanced metabolic markers. This study supports recommending the use of an EMS massage belt as part of a comprehensive strategy to optimize abdominal muscle strengthening exercises.

Keywords: Abdominal stimulation, Electrical muscle stimulation, Muscle fatigue, Metabolic rate

1. Introduction

The abdominal muscles play a pivotal role in initiating and facilitating both the strength and mobility of the trunk. They encompass two primary layers: the superficial layer comprises the rectus abdominis and external oblique muscles, while the deep layer consists of the oblique abdominis and transversus abdominis muscles [1,2]. The rectus abdominis and external oblique muscles, located in the superficial layer, have a vital function in protecting the organs from external forces and maintaining the spine in a neutral position when subjected to external forces [1,3]. The oblique abdominis and abdominis muscles play a crucial role in stabilizing the torso. In particular, the abdominis muscles, in coordination with the pelvic floor muscles, are among the initial muscles to contract when limbs are in motion. They also contribute significantly to maintain trunk stability while in a standing posture, thus helping to sustain proper posture [4,5]. Weakness of trunk stabilizing muscles causes back pain, so activation of trunk muscles is essential to maintain back stability [4,6].

The most common abdominal muscle strengthening exercises used by professionals as well as amateurs are curl-up, plank exercise with his variations, bridge, and abdominal crunch exercises. [7,8,9]. Those abdominal exercises listed above target abdominal muscles, pelvic floor, and core muscles and activate them while reducing spinal load, which are also beneficial in stabilizing the lower back for individuals with abdominal and low back muscle weakness or low back pain [10,11].

To address patients' diverse treatment goals (i.e., muscle strengthening, reducing abdominal fat, waist circumference), therapists usually utilize various techniques including therapeutic modalities such as heat interventions or electrical muscle stimulation (EMS) belts associated with abdominal exercise [12]. Among previous studies, Porcari et al. [13] applied neuromuscular electrical stimulation (NMES) to the abdomen, resulting in a significant increase in abdominal muscle strength and endurance, and a decrease in abdominal and waist girth. Kemmler et al. [14] in their systematic review found that applying EMS to the entire body led to an increase in skeletal muscle mass in the limbs and a decrease in body fat. Moreover, Han et al. [15] reported that agility and endurance increased as a result of the simultaneous application of EMS to squat motion, and the thickness of the vastus medialis, rectus femoris, rectus abdominis, external and medial oblique muscles increased, Yoo et al. [16] reported that muscle thickness, physical performance, and body composition increased as a result of applying exercise and EMS to thirty-nine subjects. They conclude that EMS can provide safe stimuli and is adequate for improving physical fitness in healthy individuals. As discussed above, the result of previous studies when EMS and other therapeutic modalities were applied during exercise demonstrated that there was a change in thickness from the rectus abdominis muscle located in the superficial layer to the abdominis muscle located in the deepest layer. However, it remains unclear whether the use of an EMS massage belt in combination with abdominal exercises yields significantly greater effectiveness compared to solely performing abdominal strengthening exercises. In addition, the majority of prior research has primarily focused on assessing changes in the abdominal muscle thickness through the application of both abdominal exercise and EMS/NMES [17-20]. However, no studies compared the change in abdominal muscle fatigue, waist circumference, body composition, and cardiovascular function on both superficial and deep muscles when utilizing an EMS massage belt during exercise.

Therefore, the purpose of this study was to investigate the effect of a novel Hot Circle EMS massage belt during abdominal strengthening exercises on waist circumference, body composition, abdominal muscle fatigue and temperature, metabolic rate, and cardiovascular function in healthy young females.

2. Materials and Methods

2.1. Study Design

This research employed a randomized, placebo-controlled trial design featuring pre-test and post-test evaluations. The study unfolded within the Department of Physical Therapy at Sun Moon University in South Korea.

2.2. Study Participants

The study encompassed twenty-two (22) healthy female university students aged between their 20s and early 30s. Inclusion criteria stipulated good overall health, absence of recent health complications, infrequent exercise habits (no more than 1 session per week), and no restrictions or contraindications for electrical heat. Exclusion criteria comprised individuals experiencing back pain in the last 3 months, regular engagement in abdominal muscle exercises in the preceding 3 months, possession of a cardiac pacemaker or contraindication for EMS, and pregnancy. Thorough explanations about the study were provided to all participants, and inclusion was contingent upon voluntary agreement and the provision of signed consent.

2.3. Sample Size Calculation

To determine the requisite sample size, G-power version 3.1.9.7 software (Heinrich Heine University, Düsseldorf, Germany) was utilized. The analysis of variance (ANOVA) was employed, considering repeated measures, within–between interaction, an effect size of 0.2, an alpha level set at 0.05, power (1-b) at 80%, two groups, nine measurements, and a nonsphericity correction of 1. The calculation yielded a required sample size of 22, distributed with 11 participants per group. The study flow diagram is visually presented in Figure 1 for reference.

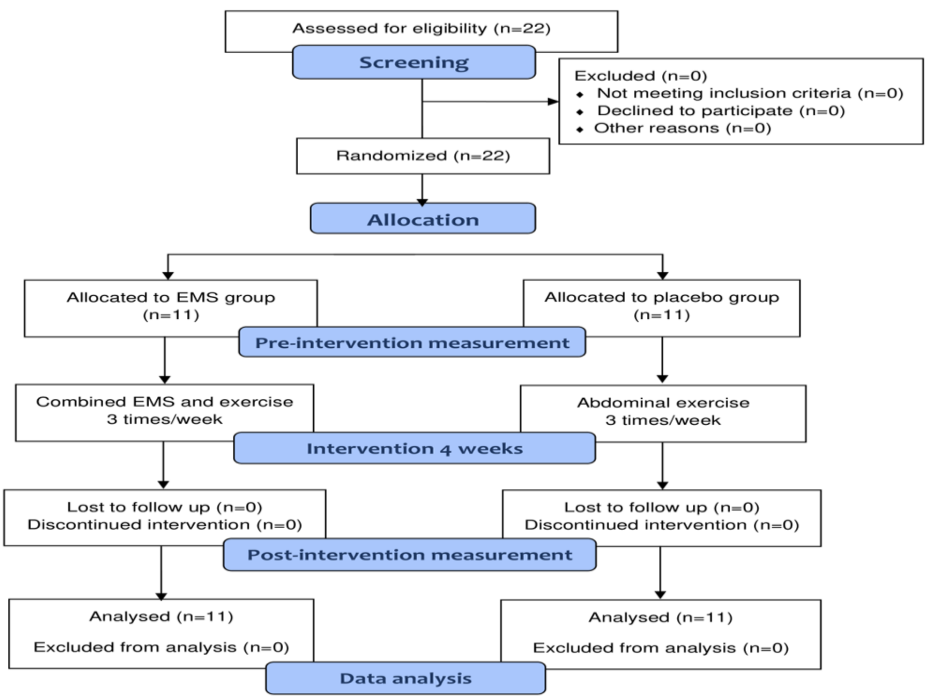

Figure 1. Study flow diagram

2.4. Intervention methods

In this investigation, participants in the Experimental Group engaged in a targeted regimen employing the innovative Hot Circle EMS massage belt (Hot Circle EMS Massage Belt, SPCARE Inc., South Korea). This novel abdominal massage belt featured a combination of heat and EMS with two strategically positioned electrode pads and offered a versatile array of therapeutic options, including 2 heating modes and 7 distinct massage stimuli modes, each customizable with various intensities. Precisely positioned between the 12th ribs and the iliac crest, the Hot Circle EMS belt ensured comprehensive stimulation, covering both the front and lateral aspects of the abdominal wall. Notably, the device boasted a maximal intensity capability of 75 mA, factoring in a 500-ohm impedance and a peak voltage of 220 volts.

During the exercise sessions, participants exercised autonomous control over the EMS stimulation, adjusting it to a personally comfortable intensity level. This adjustment corresponded to perceived exertion ratings of "somewhat severe" and "severe" on the Borg CR10 Scale, enhancing individualized comfort during the intervention. Conversely, individuals in the Control Group adhered to an identical exercise protocol, employing the same abdominal belt; however, the EMS functionality remained inactive, ensuring an absence of electrical stimulation. The comprehensive exercise routine comprised 2 sets of 10 repetitions for each of the following maneuvers: (i) deep breathing in a standing position, (ii) stationary trunk rotation for both left and right sides, (iii) hip rolling exercises in a supine position, (iv) trunk curl-up in a supine position, and (v) seated knee tuck exercises. A standardized rest period of 90 seconds was granted between sets, optimizing the consistency of the exercise sessions.

2.5. Outcome measurement

This study comprehensively assessed various outcome measures encompassing body composition (body mass, body mass index, and body fat), waist circumference, cardiovascular function (respiratory exchange ratio, heat rate, resting metabolic rate or calorie), abdominal muscle fatigue, and muscle temperature.

For precise body composition evaluation, the InBody 570 (InBody Co., Ltd, Seoul, South Korea), a commercially available body composition analyzer, was employed. This advanced apparatus utilizes a technique known as bioelectrical impedance analysis to measure crucial metrics such as body weight, body mass index (BMI), and body fat percentage. Participants received specific instructions to enhance the accuracy of the assessment. They were advised to maintain their regular hydration levels throughout the day, ensuring optimal conditions for the bioelectrical impedance analysis. To further refine the testing experience, participants were instructed to abstain from food and drink for 3-4 hours before the testing session. Additionally, to minimize potential confounding factors and ensure the utmost precision, participants were encouraged to utilize restroom facilities before the commencement of the body composition analysis. This meticulous approach aimed at securing reliable and comprehensive data, contributing to the robustness of the study's findings.

The waist circumference assessment followed a designed protocol to ensure accuracy and consistency. Conducted in the horizontal plane, a measuring tape was utilized at the hip level, precisely at the superior border of the iliac crest. Participants were guided through the measurement procedure following a normal expiration, maintaining a regular breathing pattern. The measurements were administered by a skilled physiotherapist, well-versed in the intricacies of the process. The physiotherapist took special care to secure precision by ensuring that the measuring tape was snug around the waist, maintaining a firm fit without compressing the skin. Importantly, the tape was positioned parallel to the floor, aligning with established measurement standards [21].

The cardiovascular function of study participants was continuously monitored through continuous real-time heart rate monitoring. This was achieved using the Polar H10 wireless heart rate monitor, a device known for its precision. The Polar H10 was seamlessly connected to an Android device via Bluetooth 4.0, ensuring a reliable data link. Positioned securely over the sternum with a flexible chest strap, the Polar H10 provided a dynamic and uninterrupted recording of heart rate variations throughout the study sessions. The study employed the TrueOne 2400 computerized metabolic measurement system, manufactured by Parvo Medics, Inc. based in Salt Lake City, USA. This comprehensive system utilized cutting-edge technology for metabolic assessments, including respiratory exchange ratio (RER) and metabolic rate/caloric expenditure measurements. The system featured a Hans Rudolf 3813 pneumotachometer, an instrument designed to measure ventilation. This was complemented by a mixing chamber system employing a paramagnetic oxygen analyzer (range 0–25%) and an infrared, single-beam, single-wavelength carbon dioxide analyzer (range 0–10%) [22].

The evaluation of abdominal muscle fatigue centered on the rectus abdominis and external oblique muscles. This was accomplished using the portable 4-channel Muscle Tester BTS-FREEEMG, developed by BTS Bioengineering Corp in Seoul, Korea. The system employed bipolar pre-gelled surface electrodes to capture electromyographic (EMG) signals emanating from the targeted muscles. Raw EMG amplitude values (mV) were automatically computed from the transmitted data to a personal computer. This calculation spanned a timeframe corresponding to both the initiation (start stimuli) and cessation (end stimuli) of the muscle activity. Initially presented as absolute root-mean-square amplitude values, the stored raw EMG data underwent a subsequent transformation. This involved a normalization process facilitated by dedicated software, converting the values into maximal voluntary contraction (MVC) units. This meticulous approach ensured a standardized and quantifiable measure of abdominal muscle fatigue.

The IRIS-XP Infrared Imaging System, a medical infrared thermograph, played a dual role in visualizing and quantifying pain. Equipped with an infrared camera unit, it generated color images by detecting infrared rays emitted from the human body. In the context of this study, the focus of imaging was directed specifically at the abdominal muscles. The system not only provided a real-time visualization of temperature changes in the abdominal region but also facilitated the storage of this data for subsequent analysis. By integrating infrared imaging, the study aimed to capture and elucidate thermal dynamics in the abdominal muscles, contributing valuable insights into the potential correlation between temperature variations and muscle fatigue. Figure 2 illustrates the diverse and sophisticated outcome measurement methods employed in the study (A: Body composition measurement, B: Muscle fatigue measurement, C: Metabolic test, D: Muscle temperature measurement).

(A)

(B)

(C) (D)

Figure 2. Outcome measurements, A: Body composition, B: Muscle fatigue, C: Metabolic test, D: Muscle temperature

2.6. Data analysis

The collected data from this study underwent thorough statistical analysis using IBM SPSS version 29.0 (SPSS Inc, Chicago, IL, USA). The general characteristics of the participants were initially explored through descriptive statistics, offering a summary overview of key demographic variables. To assess the divergence in mean changes between the EMS group and the placebo group, the Mann–Whitney U-test was applied. The Shapiro-Wilk test was utilized to scrutinize the normality of both demographic data and outcome variables. The identification of abnormal distribution in some data prompted the adoption of non-parametric tests for subsequent analyses. The Wilcoxon-signed-rank test was conducted to scrutinize changes over time within each group while the Mann–Whitney U-test was employed to compare differences in values between the EMS and placebo groups. The significance level for all statistical tests was set at $p<0.05$, ensuring a stringent criterion for identifying meaningful results.

3. Results

3.1. General characteristics of participants

All twenty-two (22) participants successfully completed the training program, demonstrating a high level of commitment with full attendance at all intervention sessions. In the EMG group, participants exhibited an average age of (23.90±3.80) and a height of (160.90±4.94), while the placebo group had an average age of (22.45±1.12) and a height of (162.04 ±5.77). Notably, there were no statistical differences in age between the two groups, and no participant withdrawals occurred throughout the study duration.

3.1. General characteristics of participants

Within both the EMG and placebo groups, statistically significant alterations were observed in body fat and body mass index (BMI) ($p<0.05$). However, regarding waist circumference, a significant difference was exclusively noted in the EMS group pre- and post-intervention ($p<0.05$), with no corresponding significance in the placebo group ($p>0.05$). The Mann–Whitney U-test revealed significant between-group differences in body fat and waist circumference ($p=0.042$ and $p=0.031$, respectively). Detailed results of the within and between-group comparisons are presented in Table 1.

Table 1. Changes in body composition and waist circumference within and between groups

Variables	EMS group (n=11)			Placebo group (n=11)			P-value
	Pre-test	Post-test	z-value	Pre-test	Post-test	z-value	
Body mass (kg)	64.11 ± 8.58	62.18 ± 7.26	-0.756	63.77 ± 7.12	62.49 ± 7.88	-0.044	0.084
Body fat (%)	19.32 ± 1.13	17.45 ± 0.88	-2.971*	18.76 ± 0.26	17.57 ± 0.44	-2.988*	0.042*
Body mass	23.9 ±	22.9 ± 1.20	-2.497*	21.3 ±	20.4 ±	-2.382	0.155

index (kg/m²)	3.21			0.56	3.06	*	
Waist circumference (cm)	76.58 ± 9.87	74.91 ± 8.98	-2.056*	71.36 ± 5.29	69.70 ± 5.43	-1.427	0.031*

*indicates and p level less than 0.05, P-value: Mann–Whitney U-test result

3.2. Muscle fatigue, temperature, and metabolic rate

Table 2 presents a comprehensive overview of the outcomes related to cardiovascular function, muscle fatigue, and muscle temperature within and between the EMS and placebo groups. In the EMS group, significant differences between the pre-test and post-test were observed across all outcomes—resting metabolic rate, respiratory exchange rate, heart rate, muscle fatigue, and muscle temperature ($p<0.05$). Similarly, the placebo group exhibited statistically significant differences in resting metabolic rate, respiratory exchange rate, heart rate, and muscle fatigue ($p<0.05$), with the exception of muscle temperature ($p>0.05$).

Significantly divergent results were noted between the EMG group and the placebo group in muscle fatigue and muscle temperature ($p=0.047$ and $p=0.038$, respectively). These findings underscore the distinctive impact of the Hot Circle EMS intervention, highlighting its efficacy in inducing notable changes in muscle fatigue and temperature compared to the placebo group.

Table 2. Changes in cardiovascular function, muscle fatigue, and muscle temperature

Variables	EMG group (n=11)			Placebo group (n=11)			P-value
	Pre-test	Post-test	z-value	Pre-test	Post-test	z-value	
RMR (kcal·d^{-1})	1711 ± 227	1643 ± 240	-2.658*	1712 ± 215	1680 ± 292	-2.017*	0.147
RER (ratio)	0.82 ± 1.14	0.80 ± 1.16	-2.403*	0.79 ± 0.03	0.77 ± 0.15	-2.056*	0.058
Heart rate (bpm)	119.48 ± 1.59	115.86 ± 1.05	-2.694*	119.46 ± 1.88	117.46 ± 0.75	-2.379*	0.064
Muscle fatigue (%MVC)	22.81 ± 4.18	26.48 ± 3.12	-2.190*	21.40 ± 4.42	23.18 ± 4.04	-2.118*	0.047*
Muscle temperature (°C)	35.46 ± 2.31	39.59 ± .4.15	-2.282*	35.36 ± 1.84	36.03 ± 1.68	-1.601	0.038*

*indicates and p level less than 0.05, P-value: Mann–Whitney U-test result, RMR: resting metabolic rate, RER: respiratory exchange rate, MVC: maximal voluntary contraction

4. Discussion

This study aimed to investigate the effect of a novel Hot Circle EMS massage belt (a combination of heat and EMS) during abdominal strengthening exercises on waist circumference, body composition, abdominal muscle fatigue and temperature, metabolic rate, and cardiovascular function in healthy young women. The main findings are that using an EMS massage belt during abdominal strengthening exercises is more effective in decreasing body fat, body mass index, waist circumference, resting metabolic rate (calorie rate), and respiratory exchange rate. Additionally, it increases abdominal muscle fatigue threshold as well as muscle temperature. When compared to the placebo group which also showed an increase in the majority of outcomes, the EMS massage belt is significantly superior in reducing waist circumference and increasing muscle fatigue threshold and muscle temperature.

Numerous prior studies have investigated the dynamics of abdominal muscle activation and thickness, with a predominant focus on the concurrent application of exercise and EMS [17-20]. In contrast, our present study places a distinct emphasis on exploring changes in body composition, muscle fatigue, and cardiovascular functions. The noteworthy reduction in body fat observed in both the EMS and placebo groups following four weeks of abdominal strengthening is a pivotal finding. This phenomenon signifies the body's heightened demand for energy as a compensatory mechanism during and post-exercise. The process involves the mobilization of reserved fat, a known energy source released into the bloodstream, subsequently reaching muscles to fuel their activity [23]. The magnitude of energy production during this fat oxidation process correlates with the exercise intensity, aligning with the energy demand of the exercise regimen. Moreover, the post-exercise period necessitates additional energy, primarily allocated to muscle cell recovery and the replenishment of glycogen stores within muscles [24]. In essence, optimal bodily function during and after strengthening exercises hinges on the efficient utilization of energy, derived from burning fat after tapping into primary energy sources such as carbohydrates and proteins. The present study highlights the correlation between abdominal strengthening exercises, energy expenditure, and subsequent fat utilization, shedding light on the physiological mechanisms that support effective exercise and recovery.

Changes in body mass index may result directly from changes observed in body mass as it is one of the main components of body mass index (body mass index = weight in kilograms divided by height in meters squared) [25]. A previous study documented a decrease in overall body weight and observed favorable changes in female body composition, findings that align with our own research [26]. In our study, despite that there was no statistically significant difference in body mass in both groups, we still can observe a decrease in mean value indicating a reduction in body mass which principally influences the changes in body mass index. Although applying an EMS massage belt during exercise would impact body mass, its effects are less significant. Moreover, it is important to mention that subjects in our study were not controlled for their daily physical activities routine and diet behavior which could have significantly affected the result of this study.

Waist circumference was significantly reduced in the EMS group compared to the placebo group indicating a physiological effect of EMS stimuli on waist tissues. Nevertheless, a possible association between waist circumference decrease and body mass index cannot be ignored. Previous studies affirmed that the initial body mass index of subjects and the intensity of the exercise performed influenced the changes in waist circumference after 12 weeks of resistance exercise [27,28]. Moreover, we can hypothesize that adding EMS stimuli to abdominal strengthening exercises may have increased the energy consumption which led not only to a body mass index reduced but also to a waist circumference decrease. These are the potential explanations for the results found in the present study. The EMS waist belt used in this study consists of 1 to 7 different modes, and various intensities capable of stimulating deep abdominal muscles. Contrary to other devices that only stimulate superficial muscles, the Hot Circle EMS massage belt (SPCARE Inc, Korea) has the potential to stimulate both superficial and deep abdominal muscles.

The Hot Circle EMS massage belt, as elaborated earlier, offers comprehensive coverage of the entire abdominal muscle region. Coupled with its inherent heating effect, this innovative device contributes to an elevation in muscle temperature, facilitating the elimination of residual byproducts post-strengthening exercises. The heightened respiratory exchange rate observed with its usage further translates to increased caloric expenditure, subsequently elevating the resting metabolic rate. Insights from Enoka and Duchateau [29] emphasize that the accumulation of metabolites within muscle fibers is a key contributor to muscle fatigue. The accelerated respiratory exchange associated with the EMS massage belt significantly mitigates the accumulation of these metabolites. Through consistent use over a 4-week period, abdominal muscle endurance likely experienced an enhancement, contributing to an increased muscle fatigue threshold. Crucially, the intricate relationship between muscle fatigue and muscle temperature comes into play. Higher temperatures correlate with a reduction in muscle fatigue, a phenomenon well-supported by the findings of Roots et al. [30]. Their study consistently demonstrated the influence of temperature on muscle fatigue under varying conditions. Therefore, the application of the EMS massage belt not only enhances muscle endurance but also, by virtue of increased temperature, contributes to a reduction in fatigue. In light of these observations, it can be confidently asserted that the incorporation of an EMS massage belt during abdominal strengthening exercises yields superior benefits compared to engaging in exercises alone. This commercially available device, with documented clinical advantages, emerges as a versatile tool catering to diverse fitness goals, encompassing the reduction of abdominal fat and the enhancement of muscle endurance.

It is important to recognize and address the limitations inherent in this study. Firstly, the exclusive inclusion of women in their 20s and 30s as study participants restricts the generalizability of the findings to men and individuals across different age groups. Future studies should aim for more diverse participant demographics to enhance the applicability of the results to a broader population. Secondly, despite conducting a sample size calculation and having 22 participants with 11 in each group, the study's sample size may still be considered relatively small. This could potentially impact the statistical power and generalizability of the results. Larger sample sizes in future studies would contribute to more robust and widely applicable findings. Thirdly, the study's duration of four weeks, while providing valuable insights, is relatively short. A more extended experimental period would have allowed for a more comprehensive evaluation of the long-term effects of using EMS massage belts. Future research endeavors should consider implementing prolonged intervention periods to capture sustained impacts and potential changes over time.

5. Conclusion

The purpose of the current study was to assess the impact of an innovative Hot Circle EMS massage belt (a combination of heat and EMS) during abdominal strengthening exercises on various parameters, including waist circumference, body composition, abdominal muscle fatigue and temperature, metabolic rate, and cardiovascular function in a group of healthy young women. The findings indicate that both the EMG massage belts, and the non-EMG (placebo) belts led to significant changes in the measured variables after 4 weeks of exercise. Nevertheless, it is noteworthy that the EMG group demonstrated superior effectiveness in reducing waist circumference and enhancing muscle fatigue threshold and muscle temperature when compared to the placebo group. Based on these results, we can recommend the utilization of an EMG massage belt in conjunction with abdominal strengthening exercises for improved outcomes.

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