



Original Article

Immediate effects of transcutaneous electrical nerve stimulation on six-minute walking test, Borg scale questionnaire and hemodynamic responses in patients with chronic heart failure

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Abstract. [Purpose] This study examined the immediate effects of transcutaneous electrical nerve stimulation on a six-minute walking test, Borg scale questionnaire and hemodynamic responses in patients with chronic heart failure. [Subjects and Methods] Thirty patients with stable systolic chronic heart failure came to the pathophysiology laboratory three times. The tests were randomly performed in three sessions. In one session, current was applied to the quadriceps muscles of both extremities for 30 minutes and a six-minute walking test was performed immediately afterward. In another session, the same procedure was followed except that the current intensity was set to zero. In the third session, the patients walked for six minutes without application of a current. The distance covered in each session was measured. At the end of each session, the subjects completed a Borg scale questionnaire. [Results] The mean distance traveled in the six-minute walking test and the mean score of the Borg scale questionnaire were significantly different across sessions. The mean systolic and diastolic pressures showed no significant differences across sessions. [Conclusion] The increase in distance traveled during the six-minute walking test and decrease in fatigue after the use of current may be due to a decrease in sympathetic overactivity and an increase in peripheral and muscular microcirculation in these patients.

Key words: Chronic heart failure, Electrical stimulation, Function

(This article was submitted Aug. 1, 2017, and was accepted Sep. 20, 2017)

INTRODUCTION

Cardiovascular disease (CVD) is the most widespread cause of death at present. CVD causes of about 30% of deaths worldwide, about 40% of which occur in high-income countries and 28% in low- and middle-income countries. It is estimated that CVD will be responsible for 33% of all deaths by 2030¹⁾.

The beneficial effect of cardiac rehabilitation for different groups of cardiac disorders has been proven²⁾. Cardiac rehabilitation can improve cardiopulmonary function and restore a desirable level of physical, physiological and social improvement to individuals²⁾. In addition, it reduces heart attack recurrence and lowers mortality rates. It is necessary to continue aerobic exercises during cardiac rehabilitation for several weeks after the occurrence of the event. Many patients, however, are unable to perform these exercises due to cardiac or non-cardiac difficulties such as fatigue, dyspnea and psychiatric and neuromuscular problems²⁾.

Chronic heart failure (CHF) is increasing globally¹⁾ and the decrease in tolerance of exercise in CHF patients is wide-

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spread. Sympathetic overactivity that directly causes the initiation and progression of heart failure has been observed in these patients. Sympathetic overactivity is an essential factor when predicting morbidity and mortality. The consumption of medicines such as beta-blockers to reduce overactivity of this system is one treatment goal at present³. Left ventricular dysfunction, elevated peripheral vascular resistance and reduced skeletal muscle perfusion cause pathophysiological symptoms in these patients. This is characterized by the atrophy of skeletal muscle, changes in the fiber composition, a decrease in capillary density and cytochrome oxidase activity⁴.

Exercise can improve symptoms and reduce disability in this group of patients because it can reduce sympathetic activity at rest³. Although exercise may be an appropriate treatment strategy for patients with mild or moderate symptoms, they may not be applicable to patients with severe symptoms caused by hemodynamic disturbances or movement problems caused by muscular atrophy and respiratory dysfunction. Alternative or facilitatory methods of performing exercise, therefore, may be useful strategies for these patients^{4, 5}.

Low-frequency electrical stimulation can improve peak oxygen consumption, fatigue tolerance, effective muscular strength and mass, quality of life, daily activity and blood flow velocity^{5, 6}. Despite all these advantages, only a limited number of muscles can be involved using electrical stimulation and its application for many muscles is time-consuming. This means that its usefulness may be less than that of aerobic exercises; thus, application of a modality that prepares the patient for aerobic exercises can be helpful. It has been suggested that transcutaneous electrical nerve stimulation (TENS) could reduce the sympathetic activity by reducing pain³. On the other hand, some studies have reported that TENS may affect the autonomic nervous system by reducing overactivity of the sympathetic nervous system, even in the absence of pain⁷.

To the best of our knowledge, no study has yet investigated the effects of TENS on the functional activity of the patients with CHF. A simple six-minute walking test (6MWT) can be useful for objectively assessing exercise capacity in such patients⁹. It is important to study the effects of TENS on the functional capacity of CHF patients who are not able to tolerate aerobic exercises. Previous studies have investigated the effects of TENS on the functional capacity of CHF patients either at rest or when using a pacemaker¹⁰. The aim of the present study, therefore, was to investigate the immediate effects of TENS on a 6MWT, a Borg scale questionnaire and hemodynamic responses.

SUBJECTS AND METHODS

Thirty-four patients with stable systolic CHF (all were assessed as New York Heart Association class II or III) volunteered to participate in the present study. But, only 19 males (56.5 ± 11.8 years) and 11 females (57.3 ± 9.6 years) completed all testing procedures. They were referred by cardiologists from several specialized cardiovascular clinics. Their mean left ventricular ejection fraction as determined by echocardiography was $33\% \pm 5.35\%$.

All the patients took their ordinary medicine. All participants signed informed consent forms as approved by the ethics committee of Tehran University of Medical Sciences (IR.TUMS.REC.1394.970). Subjects that had been symptomatically stable for about two months before entering the study were included. Patients with severe cardiac arrhythmia, signs of acute heart failure, an implanted cardio-defibrillator, implanted cardiac pacemaker, diabetes mellitus or unstable angina pectoris were excluded.

Each patient came to pathophysiology laboratory four times; the first session to familiarize them with the different stages of the survey and sign the informed consent form. The tests were randomly performed in the remaining three sessions. The difference in the sessions was in the application of TENS, placebo TENS or no TENS. A two-week interval was allowed between sessions.

The volunteers were requested not to consume tea, caffeine or stimulant drinks or to smoke for at least one hour before each session. All stages of the survey were performed between 10 and 12 am. At the beginning of each session, the patient sat on a chair for 10 minutes and the systolic and diastolic blood pressures and heart rate were recorded. The blood pressure was measured on the arm using a measurement device (Zyklus Conteco 80A; Germany). During the session of TENS application, TENS was applied to the quadriceps muscles of both legs simultaneously for 30 minutes at a frequency of 80 Hz and a duration of 200 μ s to a tolerable sensory threshold without muscle contraction³. For this purpose, a dual channel stimulator (COMBI-500 electrotherapy unit; Gymnauniphy; Belgium) with self-adhesive electrodes was used in the supine position. The electrodes were placed 5 cm below the inguinal fold and 5 cm above the upper patellar border¹¹. After 30 minutes of application of the stimulation, the systolic and diastolic blood pressures and heart rate were measured again. The patient was then asked to walk down a hallway and back for six minutes to cover as much distance as possible. The time remaining was announced every minute. After six minutes, the distance traveled, systolic and diastolic blood pressures, heart rate and recovery time of the heart rate were measured. Soon after, the patient completed the Borg-scale questionnaire to determine his/her rate of fatigue caused by walking.

In the placebo TENS and no TENS sessions, the same procedures were performed, except that, in the placebo TENS, the output of the stimulation intensity was set to zero. In the no-TENS session, all procedures were performed without the TENS set-up. The mean difference of systolic or diastolic blood pressure before and after 6MWT was used for statistical analysis.

Repeated measures analysis of variance (ANOVA) was used to compare the mean distance traveled during 6MWT, mean Borg scale questionnaire score and mean difference in systolic and diastolic blood pressures across sessions. A significance level of 0.05 was considered for all tests. Bonferroni post hoc adjustment was used when possible. SPSS version 22 (SPSS;

USA) was used for statistical analysis.

RESULTS

The mean distance traveled in 6MWT in the TENS, placebo TENS and no TENS sessions were 361.7 ± 88.3 , 332.3 ± 102.6 and 335.1 ± 83.9 m, respectively (Table 1). The mean distance traveled during the 6MWT was significantly different across sessions ($F=8.33$; $p=0.006$). The results of the Bonferroni tests found that the distance traveled in the TENS session was significantly greater than in the placebo TENS session ($p=0.012$) and no TENS session ($p=0.001$). There was no significant difference between the distance for the placebo TENS session and no TENS session ($p=1.00$).

The mean Borg scale questionnaire score after 6MWT in the TENS, placebo TENS and no TENS sessions were 10.8 ± 1.5 , 11.9 ± 1.5 and 11.8 ± 1.6 , respectively (Table 2). The mean Borg scale questionnaire scores after the 6MWT were significantly different across sessions ($F=14.43$; $p=0.001$). The results of the Bonferroni test showed that the mean score for the TENS session was significantly lower than for the placebo TENS session ($p=0.001$) and no TENS session ($p=0.001$). There was no significant difference for mean score between the placebo TENS and no TENS session ($p=1.00$).

The mean difference in systolic blood pressure before and after 6MWT in the TENS, placebo TENS and no TENS sessions were 8.7 ± 8.0 , 11.2 ± 9.7 and 6.9 ± 9.1 mmHg, respectively. There was no significant difference for mean difference of systolic blood pressure across sessions ($F=2.98$; $p=0.06$). The mean difference in diastolic blood pressure before and after 6MWT in the TENS, placebo TENS and no TENS sessions were 1.8 ± 4.7 , 0.4 ± 3.6 and 1.7 ± 5.4 mmHg, respectively. The mean difference in diastolic blood pressure across sessions was not significant ($F=1.12$; $p=0.33$).

DISCUSSION

The aim of the present study was to investigate the immediate effects of TENS on 6MWT, Borg scale questionnaire score and hemodynamic responses in patients with CHF. It was found that TENS improved the functional ability (distance traveled in 6MWT) of the patients. The patients also experienced less fatigue, but there was no significant difference in the systolic and diastolic blood pressure.

The increase in sympathetic activity in patients with CHF increases the progression of heart failure. Increasing of sympathetic activity may induce vasoconstriction and reduce tissue perfusion, for example, in the heart and peripheral muscles. This also reduces physical ability³).

No previous study has assessed the effects of TENS on the walking ability of CHF patients. The present study, thus, could not be compared with other studies in this regard. With regard to the hypothesis that sympathetic activity may be affected by or affect functional activities such as walking, it is possible to look at the results of some studies. Studies have shown that TENS significantly reduces mean pressure in the femoral artery and systemic vascular resistance. These effects are reported to be due to an increase in peripheral microcirculation as a result of activity inhibition of the sympathetic nervous system¹²). Chauhan et al. stated that the application of TENS can increase coronary blood flow of patients with typical symptoms of angina that had completely normal coronary arteries (confirmed by angiography) and patients with documented significant right coronary artery disease (confirmed by angiography). The same TENS stimulation had no effect on coronary blood flow of patients with heart transplants. They concluded that TENS may have an effect on the heart through changes in neural tone because, in the heart transplant group, the heart has already been innervated and coronary blood flow had not changed⁷).

Moore et al. investigated patients with chronic refractory angina through spinal cord stimulation. They found that spectral

Table 1. Mean and standard deviation (SD) of the distance (m) traveled during 6MWT for TENS, placebo TENS and no TENS conditions (n=30)

Condition	Mean	SD	Minimum	Maximum
No TENS	335.1	83.9	90	540
TENS	361.7	88.4	108	594
Placebo TENS	332.3	102.6	67	577

Table 2. Mean and standard deviation (SD) of the scores of Borg scale questionnaire after 6MWT in the TENS, placebo TENS and no TENS conditions (n=30)

Condition	Mean	SD	Minimum	Maximum
No TENS	11.8	1.62	9	15
TENS	10.8	1.50	7	14
Placebo TENS	11.9	1.47	9	15

power parameters affecting heart rate variability altered significantly. These observations were accompanied by a decrease in cardiac sympathetic activity during spinal cord stimulation. They also reported that spinal cord stimulation had a suppressive effect on intrinsic cardiac sympathetic activity in dogs in which the coronary artery had been ligated¹³.

Donadio et al. showed that skin electrical stimulation in healthy persons inhibited sympathetic activity¹⁴. Gademan et al. showed that skin stimulation improved baro-reflex sensitivity and they postulated that TENS may have affected sympathetic activity⁸. Ngai et al. investigated the effect of Acu-TENS on skin resistance and found that skin resistance at all points of application of Acu-TENS decreased in comparison with the placebo group. In addition, a significant reduction in sympathetic activity was observed¹⁵. Labrunée et al. measured the effects of skin and muscle stimulation on sympathetic nervous system activity. They showed for the first time, that these stimulations were able to reduce sympathetic activity directly. They also stated that these effects are due to sensory stimulation. They added that muscle sympathetic nerve activity was not caused by a local axonal reflex because the muscle sympathetic nerve activity was recorded from the opposite limb. The decrease in muscle sympathetic nerve activity could be due to changes in central nervous system activity. In CHF, TENS can increase the automatic baro-reflex sensitivity³.

Researchers have supposed that the release of substance P into the nucleus of a solitary tract by stimulation of muscle afferent fibers can change baro-reflex sensitivity. The change in baro-reflex sensitivity is interdependent with sympathetic outflow³. In addition to baro-reflex modulation, electro-acupuncture imposed by TENS can release opioids into the spinal cord which may inhibit sympathetic activity^{16, 17}. Furthermore, stimulation of the sensitive dorsal funiculus of the spinal cord by direct electrical impulses induces vasodilatation in the legs¹⁸. These findings indicate that electrical stimulation of afferent fibers can directly act on the sympathetic nervous system through its medullar component³.

It is known that the current induced preferentially by TENS is transmitted via the large myelinated fibers rather than the small or unmyelinated afferent fibers^{19, 20}. Thus, TENS can decrease the sympathetic tone of local organs (vessels or skin) through this medullar action³. The decrease in sympathetic overactivity after using TENS and the consequent increase in peripheral and muscular microcirculation can explain the results of the current study.

The present study was accompanied by some limitations. Some patients did not accept to participate out of fear or lack of motivation. In addition, the best way to assess sympathetic activity is through direct recording of the nervous system. Also, only CHF patients as NYHA class II or III participated in the present study.

In conclusion, TENS can reduce overactivity of the sympathetic nervous system. This may decrease the cardiac after-load and increase the capacity for functional activity in patients with CHF who are not able to tolerate aerobic exercises.

ACKNOWLEDGEMENTS

This research was part of a dissertation for doctor of philosophy (PhD) submitted to the School of Rehabilitation, Tehran University of Medical Sciences (TUMS). The authors appreciate generous support from the TUMS for funding this project.

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