Transcutaneous Electrical Nerve Stimulation Versus Treadmill Walking Exercise in Management of Intermittent Claudication

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ABSTRACT

The purpose of this study was to evaluate and compare the effect of transcutaneous electrical nerve stimulation (TENS) and treadmill walking exercise on hemodynamic measurements (ankle brachial index at rest, after exercise and laser Doppler perfusion) and on graded treadmill testing parameters (claudication onset time, maximum walking time and maximum walking distance) in patients with mild intermittent claudication (IC). Forty male with peripheral arterial occlusive disease (PAOD) from Kasr El-Aini, out patient clinic, participated in this study. The patients were randomly assigned into two equal groups; group (I) TENS group, their mean age was 59.60±4.547 years and received Burst mode- transcutaneous electrical nerve stimulation for 3 months, group (II) the exercise group, their mean age was 56.85±4.209 years and participated in exercise training program for 3 months. The results of this study showed a significant increase of graded treadmill testing parameters and laser Doppler perfusion for both groups. The results also revealed a significant increase of ankle brachial index at rest and after exercise for the exercise group while revealed a nonsignificant decrease of ankle brachial index at rest and a non significant increase of ankle brachial index after exercise for the TENS group. The results also showed a statistical significant difference among the changes of both groups except for the ankle brachial index at rest and after exercise.
Key words: *TENS - treadmill walking exercise - peripheral arterial occlusive disease.*

INTRODUCTION

Peripheral arterial disease is a widespread manifestation of systemic atherosclerosis, with an age-adjusted prevalence of 12 percent that increase to 20 percent if only persons older than 70 years are considered[14]. Claudication, defined as walking- induced pain in one or both legs (primarily affecting the calves) that dees not go away with continued walking and is relieved only be rest, is present in 15 to 40 percent of patients with peripheral arterial occlusive disease (PAOD) and is associated with a diminished ability to perform daily activities[32]. The intermittent claudication pain intensity depends on a discrepancy between oxygen supply, limited by the arteriopathy and oxygen demand by the muscles, involved in walking[17,22].

The treatment of this condition focuses on decreasing the functional impairment caused by symptoms of claudication, it is also critical to treat the underlying systemic atherosclerosis[6]. The growing recognition of the adverse effect of claudication on functional capacity, the quality of life and the observation that exercise training can serve as an effective primary nonpharmacological treatment for claudication smptoms[18,27], have led to establishment of ereceise rehabilitation program as a golden standard in management of these patients[38]. It was found that patients who exercise regularly for 3 months can double both their pain-free walking time and their maximum walking distance[3,10]. An appropriate exercise regiment may include simple walking, leg exercises and most commonly treadmill exercises[19,32] unfourtunately, not all patients could participate in exercise regimen, such as patients with lewer extremity ulcers, or whose exercise capacity is limited by symptoms of congestive heart failure, chronic obstructive pulmonary disease arthritis.

Transcutaneous electrical nerve stimulation (TENS) is typically used for alteration of pain perception[31]. several investigators[1,8,11] have hypothesized that transcutaneous stimulation of peripheral nerves, at various intensities and frequencies, can either inerease or decrease activity in postganglionic vasoconstrictor neurons. However, the effect of TENS in patients with IC has not been demonstrated, within the available literature. So, the present study was conducted to compare the effectiveness of both TENS, as a free-effort conservative modality, and treadmill walking exercise in improving exercise testing and hemodynamic parameters in patients with PAOD.

SUBJECTS MATERILALS AND METHODS

Subjects

Inclusion criteria

Forty male patients who had intermittent claudication, defined as pain in the calf, thigh, or buttocks that limited walking ability and that was relieved by rest within 10 minutes, all patients reported that claudication was the limiting symptom during community-based activities as well as with treadmill exercise in the laboratory. The severity of claudication was stable over a 3- month period before enrollment (change, <1 block in walking distance by history). The claudication pain was also considered disabling, defined as severe enough to interfere with the ability of the patient to perform social, recreational, or vocational activities, PAOD was confirmed by an ankle/ brachial systolic blood pressure ratio of <0.94 at rest that decreased to <0.85 after excrcise. So, all studied subjects had mild IC.

Exclusion criteria

They included leg pain at rest, ischemic ulceration or gangrene. Patients unable to walk on the treadmill at a speed of 2 miles per hour (mph) or whose exercise capacity is limited by symptoms of angina, congestive heart failure, chronic obstructive pulmonary disease, or arthritis were drawn out. Those who underwent vascular surgery or angioplasty within the previous year were also dropped out[20,28].

The patients were randomly divided into two equal groups; group (I) the TENS group, their mean age was 59.60±4.547 years who received burst mode TENS, subjects in TENS group were instructed to maintain their usual level of activity and not to exercise on a regular basis, group (II) the exercise group, their mean age was 56.85±4.209 years who participated in a supervised training program using treadmill exercise training.

Evaluation Procedures

The patients in both groups were evaluated pre and post treatment by measuring ankle brachial index at rest, after exercise, laser Doppler perfusion and by graded treadmill exercise test.

I- Hemodynamic Measurements

1- Ankle brachial index

At rest and after graded treadmill exercise, ankle/brachial systolic blood pressure ratios were measured as previously described[7,29]. A continuous-wave Doppler ultrasonic instrument (Parks Electronics) was used to detect the arterial pulse in both the dorsalis pedis and posterior tibial arterties in each leg and in each arm.if the two arm pressures were within 10 millimeter mercury (mm Hg), they were averaged to yield the arm pressure used for analysis, or if the difference was>10mm Hg, then the highest pressure was used (under the assumption that the higher pressure was more representative of the "true" central arterial pressure). The pressure in each ankle vessel was measured in duplicate, then averaged, and ankle/ brachial ratios were calculatede for the right and left dorsalis pedis and posterior tibial arteries. The higher pressure of the two arteries at the ankle was used for analysis at rest and after excrcise. The more diseased leg was designated as the leg with the lower ankle/ arm brachial ratio at rest. Finally, 1 minute after exercise, pressures were determined in the arm with the higher pressure at rest (ie, left or right) and in each ankle in the artery with the higher pressure at rest. Postexercise ankle/ brachial ratios were calculated from these pressures.

2- Laser Doppler perfusion

It was used for measurement of skin blood flow before and after treatment period. Studies were performed with the subject in the supine position, which was assumed 20 minutes before the experiments were started. Skin blood flow was assessed with a laser Doppler probe (PF801, Periflux, Perimed) connected to a laser Doppler flowmeter (PF5000, Perimed). A reference probe was positioned 5cm from the probe used for pressure application. This latter probe was positioned over the middle of the internal ankle bone and attached to an apparatus extensively described elsewhere[12,25,35].

II- Graded Treadmill Testing Protocol

Subjects had a familiarization graded treadmill test during the initial visit, with a second test on a subsequent day used for data analysis. The graded treadmill protocol has been described[6,16]. Subjects walked on the treadmill at an initial workload of 2mph, 0 % grade (inclination) for 3 minutes. Subsequent stages increased 3.5% in grade every 3minutes (with no change in speed) to maximal claudication pain. During exercise, heart rate (by 12-lead ECG) and brachial blood pressure were monitored every minute. Change in the severity of the claudication pain during the test was recorded on a scale of 1 to 5, with 1 indicating no pain, 2, onset of claudication, 3 mild; 4, moderate; and 5, severe pain. All subjects (at all evaluations) reached a maximal level of claudication pain that limited exercise during the graded treadmill test[24,30,37].

Treatment programs

TENS protocol: The TENS group was subjected to Burst-mode TENS stimulation,3 times a week for twelve weeks. A thorough explanation about the TENS device and the protocol of treatment was given to each patient. The Patient assumed a supine lying position on a comfortable treatment plinth with the hips and knees flexed to approximately 70 degrees. Prior to electrode placement, the skin was cleaned with alcohol soaked cotton. The electrodes from the 2-channels were enclosed in pads soaked in water. The positive (red) electrodes from the 2 channels were placed, one on the tibial nerve (where it passes in the posterior compartment of the leg just below the popliteal fossa), and the other one on peroneal nerve (where it passes behind the head of fibula to the neck). The negative electrodes were placed on the posterior calf, approximately 9-cm above the calcaneous, thus one channel was used to stimulate the tibial nerve and the other channel to stimulate the peroneal nerve. The electrodes from the 2-channels were fixed in place using straps.

Application procedures

A constant current out put with a balanced biphasic asymmetrical wave form was used. The following parameters were selected: A burst frequency of 2 burst per second (bps), a carrier frequency of 85 pulse per secend (pps) and a phase duration of 250 microsecond were used, at an intensity of 125% of motor threshold. For determination of the 125% motor threshold (MT), the TENS analog out put necessary for visible muscle contraction (motor threshold) was multiplied by 1.25[31]. Each subject received 15 minutes of burst mode TENS.

Exercise protocol: Subjects randomized to the treadmill walking exercise program were trained as previously described[17,31]. Briefly, patients reported to the rehabilitation center three times per week for 1-hour training sessions. After a 5-minute warm-up period, patients walked on a motor-driven treadmill at a rate and grade designed to produce moderate claudication pain after 3 to 5 minutes of exercise. Once the subject experienced moderate claudication pain, he would step off the moving treadmill and rest until pain subsided, then repeat this intermittent walking activity for a total of 50 minutes. At the end of each session, there was a 5-minute cool down period. The intensity of the treadmill training program was increased on a weekly basis as tolerated by increasing both walking speed and grade. Subjects were also encouraged to continue the walking program on their own an additional 2 days per week.

RESULTS

Through the present study, comparison was made by student t-test to compare the significance of difference between before and after among both groups (the TENS group and exercise group) across hemodynamic measurements (ankle brachial index at rest, after exercise and laser Doppler perfusion) and graded treadmill testing parameters (claudication onset time, maximum walking time and maximum walking distance).

I- Hemodynamic measurements:

A- ankle brachial index at rest (ABI): Table (1)

The analysis of data exhibited a non significant difference between both groups.Table (1) shows the mean difference between pre and post values of ABI at rest in both group. It was -0.004 + 0.039 in the TENS group while in the exercise group it was 0.0165 + 0.029. The mean relative change of ABI at rest decreased by -0.414% + 5.928 in the TENS group and increased by 3.152% + 5.341 in the exercise group.

B- ankle brachial index After exercise (ABI after exercise) : Table (1)

The analysis of data exhibited a non significant difference between both groups. Table (1) shows the mean difference between pre and post values of ABI after exercise in both groups. It was 0.003±0.032 in the TENS group while in the exercise group it was 0.016±0.025. The mean relative change of ABI after exercise increased by 0.878%±7.822 in the TENS group and by 3.283%±5.605 in the exercise group.

C- Laser Doppler perfusion (LDP) measured in perfusion units (PU) Table (1)

The analysis of data clarified significant differences between both groups. Table (1) shows the mean difference between pre and post values of LDP in both groups. It was 23.956±17.039 PU in the TENS group while in the exercise group it was 66.034±35.567 PU. The mean relative change of LDP increased by 25.644%±16.763 in the TENS group and by 92.675%±21.168 in the exercise group.

Table (1): Statistical comparison of studied variables (ABI at rest, ABI after exercise, LDP) before and after among both groups as regards its relative changes%.

Variable	Group	Statistical value	Before	After	Mean difference	Relative change %
ABI at rest	TENS group	Mean+S.D.	0.673+0.137	0.669+0.138	-0.004+0.039	-0.414+5.928
	Exercise group	Mean+S.D.	0.68+0.142	0.696+0.127	0.0165+0.029	3.152+5.341
	T-test	t-value	0.158	0.643	1.875	1.999
		p-value	>0.05	>0.05	>0.05	>0.05
ABI after exercise	TENS group	Mean+S.D.	0.472+0.159	0.475+0.163	0.003+0.032	0.878+7.822
	Exercise group	Mean+S.D.	0.529+0.133	0.545+0.135	0.016+0.025	3.283+5.605
	T-test	t-value	1.229	1.481	1.427	1.118
		p-value	>0.05	>0.05	>0.05	>0.05
LDP	TENS group	Mean+S.D.	102.929+37.16	126.89+43.4	23.956+17.039	25.644+16.763
	Exercise group	Mean+S.D.	91.205+39.619	157.24+48.1	66.034+35.567	92.675+21.168
	T-test	t-value	0.966	2.516	4.556	4.140
		p-value	>0.05	< 0.05	< 0.05	< 0.05

II-Graded treadmill testing parameters

A- Claudication onset time (COT)(in minutes) : Table (2)

The analysis of data revealed significant differences between both groups. Table (2) shows the mean difference between pre and post mean values of COT in both groups. It was 1.747±1.453 minutes in the TENS group, while in the exercise group it was 3.954±1.476 minutes. The mean relative change of COT increased by 47.21%±43.415 in the TENS group and by 101.463%±62.082 in the exercise group.

B- Maximum walking time (MWT) (in minutes): Table (2)

The analysis of data exhibited significant differences between both groups. Table (2) shows the mean difference between pre and post values of MWT in both group. It was 2.422±1.471minutes in the TENS group while in the exercise group it was 6.611±1.99 minutes. The mean relative change of MWT increased by 41.094%±30.581 in the TENS group and by 103.141%±47.235 in the exercise group.

C- Maximum walking distance (MWD) (in meters): Table (2)

The analysis of data showed significant differences between both groups. Table (2) shows the mean difference between pre and post values of MWD in both groups. It was 128±81.151 meters in the TENS group while in the exercise group it was 353±108.776 meters. The mean relative change of MWD increased by 41.95 %±32.252 in the TENS group and by 107.022%±50.552 in the exercise group.

Table (2): Statistical comparison of studied variables (COT,MWT,MWD) before and after among both groups as regards its relative changes%.

Variable	Group	Statistical value	Before	After	Mean difference	Relative change %
COT	TENS group	Mean+S.D.	4.374+1.525	6.121+2.003	1.747+1.453	47.21+43.415
	Exercise group	Mean+S.D.	4.839+2.159	8.793+2.481	3.954+1.476	101.463+62.082
	T-test	t-value	0.787	3.747	4.765	3.203
		p-value	>0.05	< 0.05	< 0.05	< 0.05
MWT	TENS group	Mean+S.D.	6.374+2.069	8.796+2.744	2.422+1.471	41.094+30.58
	Exercise group	Mean+S.D.	7.167+2.482	13.778+3.45	6.611+1.99	103.141+47.235
	T-test	t-value	1.097	5.051	7.57	4.931
		p-value	>0.05	< 0.05	< 0.05	< 0.05
MWD	TENS group	Mean+S.D.	334.5+110.142	462.5+148.2	128+81.151	41.95+32.252
	Exercise group	Mean+S.D.	372+131.973	725+184.15	353+108.776	107.022+50.552
	T-test	t-value	0.976	4.97	7.414	4.853
		p-value	>0.05	< 0.05	< 0.05	< 0.05

DISCUSSION

Atherosclerosis is a systemic disease affecting the entire arterial tree, but coronary artery disease, cerebrovascular disease and peripheral arterial occlusive disease (PAOD) have the most clinical significance[4,14].

Peripheral arterial occlusive disease commonly affects the major arteries supplying the leg, causing arterial stenosis or occlusion and hence restriction of blood flow. This causes patients to experience muscle pain, particularly during walking and exercise, this symptom is termed intermittent claudication (IC). Further reduction in blood flow may cause ischaemic pain to appear at rest. Ulceration and gangrene may then supervene and, if not treated, can result in loss of the limb[2,12].

However, since the majority of patients with claudication are not at short-term risk of limb loss, the primary therapeutic goal is to improve exercise performance and community based functional status. Exercise training elicits well established and clinically important changes in treadmill exercise performance and community based walking ability[18].

As Burst- mode TENS can be applied in a wider population of PAOD patients than that of exercise, this study was presented to investigate and compare between the effectiveness of treadmill walking exercise and Burst – mode TENS in PAOD patients.

Transcutaneous electrical nerve stimulation.

1. Hemodynamic measurements

- Ankle brachial index

The statistical analysis of data of TENS group showed that ABI measured at rest was reduced nonsignificantly by 0.414%±5.928 while ABI after exercise showed an nonsignificant increase by 0.878%±7.822. The nonsignificant results of ABI at rest and after exercise indicate that electrostimulation had no influence on macrocirculation. It was suggested that the overall perfusion is not influenced by electric stimulation because ABI was not changed either at rest or post exercise[1,33]. However, while ABI measurements are good in predicting the severity of arterial disease, they can not discriminate redistribution of perfusion within the ischemic limb.

- Laser Doppler perfusion

The current study showed a significant increase in laser Doppler perfusion by 25.644%±16.763 in the TENS group. This significant increase implies a cutaneous vascular effect. The enhancement of skin blood flow is attributed to local mechanisms. The muscle pump, accumulation of local metabolic vasodilator substances (such as hydrogen ion, adenosine or phosphate) and flow induced vasodilation produced by local release of relaxing factors derived from the endothelium[31,23]. It was concluded that low frequency electrical stimulation improved skin oxygen saturation and so it lead to healing of ulcers[8,33].

Laser Doppler flowmetry study of skin blood flow in response to TENS applied to 57 diabetic subjects including uncomplicated and complicated diabetics, showed an increase in skin blood flow on the dorsum of the foot without any significant difference between the different groups. This came in agree with the results of the current study[11,23].

2. Treadmill exercise testing parameters

The results of the present study revealed that TENS significantly increased claudication onset time by 47.21%±43.415, maximum walking time by 41.094%±32.252 and maximum walking distance by 41.95%±32.252. Although not measured in this study, the recovery period from claudication pain reported by patients reduced with TENS. Also healing of wounds occurred during treatment period was faster. These results may be attributed to contribution of many mechanisms.

Stimulation could exert its beneficial effects on treadmill testing parameters by altering metabolic efficiency of the targeted muscle. This was explained by several studies. In claudicants, the muscle contraction is characterized by faster time to peak contraction, and inability to regain baseline between contractions due to slowing of muscle relaxation. This is due to the observed increase in fast myosin heavy chain and change in fiber population towards the fast type in ischemic muscles of PAOD patients. Slower relaxation has been attributed to falling of muscle PH to a greater extent in claudicants than healthy age-matched controls. This affects Ca^{2+} pump rate of the sarcoplasmic reticulum which results in early fatigue and reduced exercise tolerance[16]. After TENS application, the muscle contraction is characterized by longer time to peak contraction and elimination of slowing of muscle relaxation[1]. This would delay fatigue and explain the observed increase in COT, MWT and MWD on exercise testing.

The improvement in the total work load capacity of the claudicant leg up to the appearance of ischemic pain suggests that the electric current improves total oxygen inflow and delivery of blood to the exercising muscle. The absence of hemodynamic changes at the macrocirculatory level showed that electric current has no influence on the global blood flow of the diseased leg but probably enhances oxygen delivery to ischemic tissues through redistribution of blood flow, with improvement of capillary perfusion, and may result in optimization of oxygen consumption[33].

This would necessitate alterations in the fine control of arterial vessels that regulate perfusion through individual muscle capillary beds. Disturbances of resistance vessel control have been demonstrated in POAD patients. There is a reduced calf reactive hyperemic responses to thigh occlusion and depressed endothelial and smooth muscle function in resistance arteries. Impaired vasodilator responses of the smallest arterioles in ischemic limb skeletal muscle is a very early feature, whereas changes in fiber type or metabolism are late features. Low frequency electrical stimulation applied intermittently to ischemic rat hind limb muscles has restored dilator capacity to these vessels, and enhanced hyperemia in response to muscle contractions[1].

A vascular effect of stimulation that would optimize calf muscle perfusion is, therefore, a possible contributory factor in the improved walking ability of patients receiving TENS treatment in this study. Also one possible mechanism of electric stimulation effect on circulation could be related to its influence on the risk factors of atherosclerosis. In electrostimulated patients, a significant decrease of low density lipoprotein (LDL) cholesterol during treatment was observed[33].

Treadmill walking exercise:

1. Hemodynamic measurements

- Ankle brachial index

ABI showed small pressure changes after training in this study. ABI at rest increased significantly by 3.152% + 5.341 and after exercise by 3.283% + 5.605. Changes in collateral artery resistance can be assessed accurately by measuring resting ABI. Post exercise ABI is an even more sensitive indicator of the functional state of collaterals. This suggests that factors other than increased development of collateral vessels are involved. This is confirmed by many studies which reported that little or no increase in absolute blood flow after training were found[13,15,20,21].

The majority of exercise training studies in PAOD patients show that limb blood flow is not enhanced. It was concluded that the increase in lower limb blood flow was small while exercise tolerance regularly increased by over 100% as in our study[13,36]. Therefore, an improvement in blood flow is not a prerequisite for successful exercise training. The flow increase could account for only 5.30% of improvement in walking distance[34].

- Laser Doppler perfusion

Treadmill training also showed a statistical significant increase in LDP by 92.675% + 21.168 The significant improvement of LDP noted in the present study may be attributed to the role played by endothelium- derived nitric oxide (NO). At rest and during exercise, endothelium derived NO plays a role in matching blood flow to tissue metabolism. Chronic physical activities have been demonstrated to increase circulating plasma levels of nitrites and nitrates. These metabolites result from NO oxidation and therefor used as a biochemical marker of endogenous NO production[5]. It was demonstrated that aerobic exercise could enhance cutaneous vascular responsiveness to endothelium dependant vasodilator (i.e. NO) .The higher levels of NO can decrease the resistance of cutaneous vasculature, thereby increase skin blood flow[36]. Thus the exercise-induced improvements in cutaneous blood flow are the results of increased NO production or a lower resistance to NO. Skin blood flow is crucial to maintain the flow of nutrients to that area, regulating body temperature, and in healing of any cutaneous injuries. The results of the current study agreed with Colberg et al,[5] who examined the relationship between aerobic training and skin blood flow in type 2 diabetes. It was measured noninvasively by continuous laser Doppler assessment in response to various stimuli. Training group had enhanced baseline and ischemic reperfusion induced blood flow. Thereby it was concluded that aerobic activities are associated with enhanced skin blood flow in type 2 diabetes. So, regular physical activity may be a valuable tool in the prevention and reversal of defective skin vasodilation and resultant foot ulcers.

Exercise program is a non invasive, inexpensive, has minimal complications and produces a significant improvement in treadmill testing parameters.

Treadmill exercise testing parameters

The statistical analysis of data of the exercise group showed that the treadmill training program significantly increased claudication onset time by 101.463%±62.082, maximum walking time by 103.141%±47.235 and maximum walking distance by 107.022%±50.522 . Although not measured in this study, the recovery time from claudication pain became shortened and the severity of claudication pain was lessened.

In patients with PAOD, increasing the workload causes an inequality in the supply of and demand for oxygen. Aerobic generation of adenosine triphosphate (ATP) becomes inadequate and anaerobic metabolism predominates. The result is an increase in lactic acid production, and a depletion of ATP and creatine phosphate, leading to pain. Compared with normal subjects, the recovery of high-energy phosphate substrate in the muscles is slower and so patients with PAOD have both a poor physical tolerance to exercise and a prolonged recovery time[1,34]. Exercise training of PAOD patients is well known to alleviate some of these alterations. Several mechanisms are involved in explanation of this improvement. Changes that occur after a period of exercise training in patients with PAOD are similar to those in normal subjects. There are numerous changes in muscle structure and function in normal subjects as a response to exercise training. There is an increase in the number of mitochondria per muscle fiber, a higher level of oxidative enzymes, a slower utilization of muscle glycogen and blood glucose, and a greater reliance on fatty acid oxidation. The respiratory exchange ratio (carbon dioxide production: oxygen utilization) diminishes as a result of the increase in fatty acid oxidation[26].

Femoral venous blood from claudicants who complete an exercise program had a lower lactic acid concentration than was recorded before training[17]. Less phosphocreatinine depletion (Phosphocreatinine depletion is a measurement of energy utilized for exercise) was also found. These changes indicate greater ATP production, less reliance on anaerobic metabolism and so improvement in muscle energy state[9].

Improvements in exercise performance may be attributed to reversal of low oxidative capacity of the muscles. After an exercise training program, significant increases in the levels of oxidative enzymes such as cytochrome oxidase and succinic oxidase had been reported, with a small rise in citrate synthase. Patients with a low level of cytochrome oxidase (compared with normal) before training had a markedly improved level on completion of an exercise program. The low enzyme activity before training may result from reduced physical activity, muscle fiber depletion or mitochondrial damage secondary to ischemia. Therefore, exercise training may reverse the low oxidative capacity of the muscles[34].

It was explained that in claudicants, the respiratory exchange ratio for a given workload decreases after training. This is similar to the response of normal individuals and represents an enhancement of fatty acid oxidation. Fatty acids can only be metabolized aerobically in the mitochondria to produce ATP. This suggests greater oxidative capability, either an increase in mitochondrial function (as measured by oxidative enzyme activities) or by better oxygen delivery. Regarding anaerobic capacity, exercise training does not alter it as proven by a constant level of lactate dehydrogenase[34].

Also, the significant increase in treadmill test parameters was correlated with a reduction in plasma acylcarnitine. Acylcarnitine is a marker of metabolic dysfunction and is linked to the limitation in physical tolerance of patients with PAOD. After exercise training, a reduction in plasma acylcarnitine level correlates with an increase in maximum walking distance. Patients who achieve a higher peak oxygen uptake following an exercise program have a greater reduction in muscle acylcarnitine level than those who do not improve their oxygen uptake[19,34].

Reduction of oxygen cost for the same workload is another suggested mechanism of improvement. Patients with PAOD, may respond to an exercise rehabilitation program by showing a decrease in steady-state oxygen utilization during treadmill testing. This reduction implies that the oxygen cost for the same workload has decreased. As most patients with peripheral arterial disease are smokers and likely to have reduced respiratory function, the reduction in oxygen cost may be an important factor leading to an improvement in physical tolerance[17].

Also improvement in the biomechanics of walking can improve treadmill testing parameters. All claudicants have abnormal gait parameters compared with controls[30]. Following exercise training, a significant improvement in gait pattern was mentioned by Stewart et al,[32].

Conclusion

It was concluded that the exercise training improves the physical tolerance of patients with claudication. The muscles adapt by improving their aerobic metabolism leading to greater utilization of oxygen. Less reliance on anaerobic metabolism, reduces lactic acid production and improves the muscle energy, thereby helping to rectify the associated metabolic dysfunction. Exercise training leads to a reduction in oxygen cost of exercise, a higher peak oxygen utilization.

The results of the current study showed that exercise training program resulted in greater improvements than TENS in exercise testing parameters and in laser Doppler perfusion, however, the minimum duration of a training period, using sessions of 30 minutes up to 1 hour which were repeated several times per weak, is of the order of 3-6 months. Set against this, TENS uses simple resources, little daily time and minimum supervision. Also the magnitude of functional improvements in the present study show that TENS is an an effective and simple treatment for claudicants. Adding to this that TENS can be applied by patients themselves after explanation of equipment use, and it does not require attendance at a supervised exercise program.

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الملخص العربى

تمرينات المشى على السير مقابل التنبيه الكهربى للعصب عبر الجلد فى السيطرة على العرج المتقطع لقصور الإمداد الدموى لعضلات الرجل

هدف هذه الدراسة هو بحث ومقارنة تأثير كلاً من تمرينات المشى على السير والتنبيه الكهربى للعصب عبر الجلد على مدلولات التمرين وعلى قياسات ديناميكية الدورة الدموية وذلك لتحسين القدرة على المشى والدورة الدموية فى الجلد فى مرضى انسداد الشرايين الطرفية. ولقد أجريت هذه الدراسة على 40 مريض من الذكور يعانون من العرج المتقطع، وتراوحت أعمارهم ما بين الخمسين والخامسة والستين عامًا ولقد تم تقسيمهم إلى مجموعيتن متماثلتين . تم تمرين عشرين مريضا باستخدام تمرينات المشى على السير والعشرين الآخرين تلقوا تنبيه كهربى للعصب عبر الجلد. وأظهرت نتائج هذه الدراسة وجود زيادة ذات دلالة إحصائية فى جميع مدلولات اختبار التمرين وفى الدورة الدموية فى الجلد لكلا المجموعتين. كما أظهر التمرين زيادة ذات دلالة إحصائية فى معامل الضغط القدمى الذراعى وقت الراحة وبعد التمرين أما التنبيه الكهربى للعصب عبر الجلد فقد أظهر أنخفاض ليس له دلالة إحصائية فى معامل الضغط القدمى الذراعى وقت الراحة وزيادة ليس لها دلالة إحصائية فى معامل الضغط القدمى الذراعى بعد التمرين.

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