Vascular Response to Different Forms of Transcutaneous Electrical Nerve Stimulation

Haytham Mohamed El-Hafez*, Kadria Hosny Mohamed Battecha*, Mostafa Mahmoud Gad and Awatef Mohamed Labib***
* Basic Science Department, Faculty of Physical Therapy, Cairo University.
** Radiology Department, Faculty of Medicine, Cairo University.

ABSTRACT

Background: *Transcutaneous Electrical Nerve Stimulation (TENS) is a modality used to control pain and it was reported to influence the vascular responses to increase the blood flow volume and reduce the resistivity of the arteries in normal subjects. Although many studies were done, the effect of different forms of TENS on blood is still unclear.* ***Purpose:*** *The purpose of this study was to determine the effect of different forms of TENS on blood responses. The practical part of this study was done in Kasr Al-Aini hospital, at diagnostic radiology department.* ***Methods:*** *Forty-five normal male physical therapy students were selected with a mean age of 18.92±1.5 years, a mean height of 174±3.2 cm and a mean weight of 72.9±6.7 Kgm. They assigned randomly into three equal groups of fifteen. Group I received High TENS of 100 pps with a pulse duration of 80 μsec. Group II received low TENS of 2 pps with a pulse duration of 200 μsec. Group III received Intense TENS of 150 pps with a pulse duration of 300 μsec. The blood flow volume, peak systolic velocity, and resistivity index were measured. Doppler ultrasound was used pre and post TENS application for 20 minutes on posterior tibial nerve. Comparative analysis with repeated measurements was done to determine the significance changes in vascular responses.* ***Results:*** *There is a highly significant increase of blood flow after application of low TENS (44.74%) when compared with other studied groups, (37.41% for high TENS and 32.11% for intense TENS). Peak systolic volume showed high significant increase after application of high TENS (62.07%) when compared with other studied groups. In addition, there is a significant decrease of resistivity index after application of low TENS (-19.15%) when compared with other studied groups (-11.96% for High TENS and -10.42% for intense TENS).* ***Conclusion:*** *The effect of TENS on circulation depends on stimulation intensity and frequency. When the intensity was sufficient to cause a moderate muscle contraction a transient local increased in blood flow occurred. These findings may be attributed to stimulation of efferent fibers with intensity at motor level producing muscle contraction.*

Key Words*: Transcutaneous electrical nerve stimulation (TENS), sympathetic tone, blood flow*

INTRODUCTION

Transcutaneous Electrical Nerve Stimulation (TENS) is a modality used to control pain; it was reported to influence the vascular responses to increase the blood flow volume and reduce the resistivity of the arteries in normal subjects. Although many studies were done, the effect of different forms of TENS on blood is still unclear. The purpose of this study was to determine the effect of different forms of TENS on blood responses. The practical part of this study was done in Kasr Al-Aini hospital, at diagnostic radiology department.

TENS is defined as stimulating device that delivers electrical currents across the intact surface of the skin[10]. There was evidence that Roman physician had the first documented report of the use of electrogenic elements in medicine in AD-46[5]. Actually TENS introduced to the profession in the early 1970's and has rapidly been accepted as a standard modality in the management of pain, both chronic and acute[7].

TENS becomes quickly known in medical professions, that physician and others who have utilized TENS have reported excellent results in many aspects of practice such as obstetrics. In addition, TENS is used in pre and post-surgical pain, none united fracture pain and healing, dental and temporomandibular joint pain[6].

The electrical characteristics of TENS are chosen according to the principles of nerve fibers activation: Large diameter nerve fibers as (A□ and A□) have low thresholds of activation to Electrical Stimulation (ES) when compared with their small diameter fibers (Aδ and C). Thus, to activate large diameter fibers (A□) without activating smaller diameter nociceptive fibers (C and Aδ) one would select low-intensity, high frequency TENS (10-250 pps) with pulse durations between 10-100μs[3,12]. Increasing the pulse duration will lead to the activation of small diameter fibers at lower pulse amplitude[11].

MATERIAL AND METHODS

Forty-five normal male physical therapy students were selected with a mean age of 18.92±1.5 years, a height of 174.0±3.2 cm and a weight of 72.9±6.7 Kg. They assigned randomly into three equal groups. Group I received high TENS (100 pps of 80 μsec), group II received low TENS (2 pps of 200 μsec) and group III received intense TENS (150 pps of 300 μsec). An experimental repeated measures controlled design was used. All subjects participated in the three study conditions at three separate sessions with one-week interval between each application. The order in which the conditions were assigned and randomized at each session were: high TENS, low TENS, and intense TENS.

All subjects should avoid -two hours before session- eating, smoking, caffeine and exercising. This was done to minimize the potential effects of digestion or thermoregulatory activity and to create a stable hemodynamic state. No analgesic medication or medicine alert circulation were taken within 24 hours before session. Each subject must be free from peripheral vascular diseases, neurological conditions, diabetes, neuritis and blood pressure abnormalities.

Subjects assumed modified prone lying position for measuring blood flow volume, peak systolic velocity (PSV) and resistivity index (RI) of the sural artery (muscular branch of tibial artery) for both pre and post test. The transducer head of duplex Doppler ultrasound was positioned vertical on posterior aspect of leg after application of sufficient amount of Sono-gel. The procedure was completed by a specialist. While recording the blood flow volume, PVS and RI were done. The position of subject and transducer head were standardized for all study sessions.

The blood flow volume, peak systolic velocity, and resistivity index were measured. These parameters were measured by ultrasound Doppler pre and post TENS application for 20 minutes on posterior tibial nerve (Figure 1).

Fig. (1): Stimulation of the posterior tibial nerve with TENS

Electrical stimulation was provided with dual-channel TENS unit the stimulator connected to TENS electrodes using gel as conducting medium. The three types of TENS (high, low, and intense) were used to determine what type exactly would have the real effect on vascular system.

Before the application of TENS, certain arrangements should be considered which are: positioning the subject in a comfortable position in normal room temperature, cleaning the skin at the side of electrodes, removing any metals at the site of application.

After these precautions the following procedure was taken: 1) the stimulating electrode was placed over the tibial nerve in the popliteal fossa, while a negative electrode was placed on the belly of gastrocnemius muscle. The intensity was determined according to the form of applied TENS. TENS was delivered to the tibial nerve in the right lower limb for 20 minutes and the measurements was taken before TENS application and immediately after application.

Duplex Doppler ultrasound was used to measure blood flow volume, which is valid and reliable method of evaluation and was used in similar previous studies. The used device was the Multi-Dop P system that contains all Doppler modules required for variety of examinations (2, 4, 8 and 16 MHz) for transcranial, extracranial, peripheral and microvascular measurement of blood flow[9].

RESULTS

Blood flow (lit/min)

Table (1) and figure (2) show the mean value difference of blood flow in the three groups. In group I "High TENS group" the mean value of blood flow was 0.147±0.038 lit/min before application of high TENS (100 pps, 80 μsec). After application of high TENS, the mean value of blood flow increased significantly (0.202±0.069 lit/min). The percentage difference (% difference) was 37.41% with t= -6.984 and p<0.0001. The mean value of blood flow for group II "low TENS" (2 pps - 200 μsec) was 0.152±0.067 lit/min. After application of low TENS, the mean value of blood flow increased with no significant difference. It was 0.22±0.03 lit/min (t= -1.881 and p<0.081) with percentage difference of 44.74%. Group III "Intense TENS" (150 pps – 300 μsec) showed a mean value of blood flow of 0.109±0.011 lit/min. After application of intense TENS, the mean value increased significantly (0.144±0.029 lit/min). The mean difference was 32.11% with high significance of p<0.0001.

Table (1): Statistical analysis of mean values of blood flow (Lit/min) of all studied groups for high, low, and intense TENS pre and post-treatment

	Group I		Group II		Group III	
	High TENS		Low TENS		Intense TENS	
	Pre-TENS	Post-TENS	Pre-TENS	Post-TENS	Pre-TENS	Post-TENS
Mean	0.147	0.202	0.152	0.22	0.109	0.144
SD	0.038	0.069	0.067	0.03	0.011	0.029
% Difference		37.41%		44.74%		32.11%
t-value		-6.984		-1.881		-6.583
p		0.0001		0.081		0.0001
Significance		HS		NS		HS

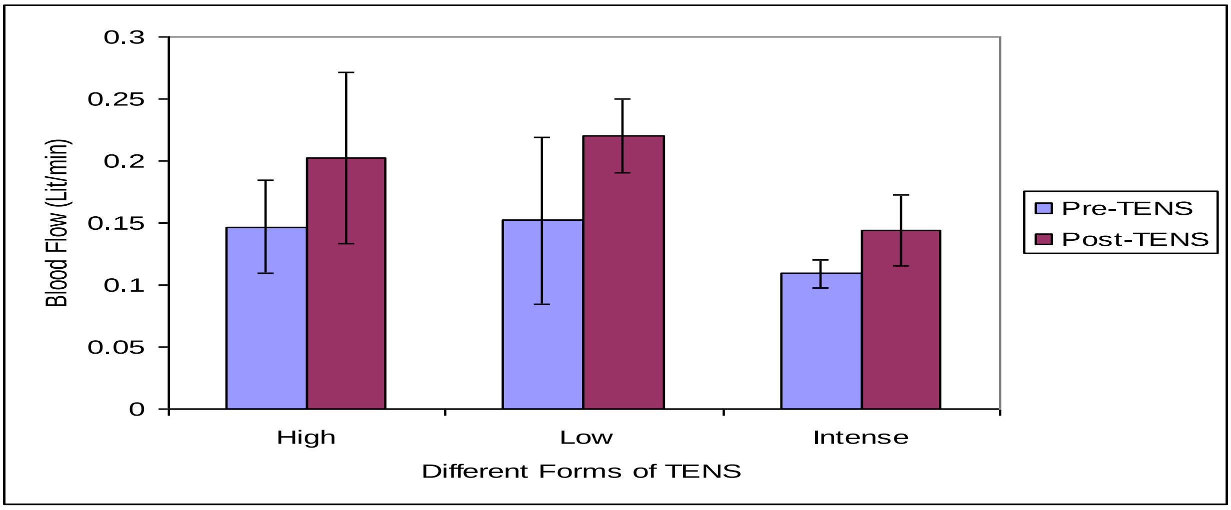

Fig. (2): Blood flow (Lit/min) of all studied groups for high, low and intense TENS pre and post-TENS application.

Peak systolic velocity (cm/sec)

Table (2) and figure (3) show the comparison of mean values of peak systolic velocities of all studied groups. Before application of high TENS (100 pps, 80 μsec), the mean value of peak systolic velocity was 43.76±12.96 cm/sec in group I. After application of high TENS, the mean value of peak systolic velocity increased significantly (70.92±5.61 cm/sec). The percentage difference was 62.07% with t= -8.7 and p<0.0001. The mean value of peak systolic velocity in group II "low TENS" (2 pps - 200 μsec) was 47.7±5.61 cm/sec. After application of low TENS, the mean value of peak systolic velocity increased significantly. It was 61.7±4.72 cm/sec (t= 2.342 and p<0.034) with percentage difference of 29.35%. Group III "Intense TENS" (150 pps – 300 μsec) showed a mean value of peak systolic velocity of 52.78±6.5 cm/sec before application. After application of intense TENS, the mean value increased significantly (58.8±8.19 cm/sec). The mean difference was 11.41% with significance level of p<0.0001.

Table (2): Comparison of mean values of peak systolic velocity (cm/sec) of all studied groups for high, low, and intense TENS pre and post-treatment

	Group I		Group II		Group III	
	High TENS		Low TENS		Intense TENS	
	Pre-TENS	Post-TENS	Pre-TENS	Post-TENS	Pre-TENS	Post-TENS
Mean	43.76	70.92	47.7	61.7	52.78	58.8
SD	12.96	5.61	13.27	4.72	6.5	8.19
% Difference		62.07%		29.35%		11.41%
t-value		-8.7		2.342		-2.601
p		0.0001		0.034		0.021
Significance		HS		S		S

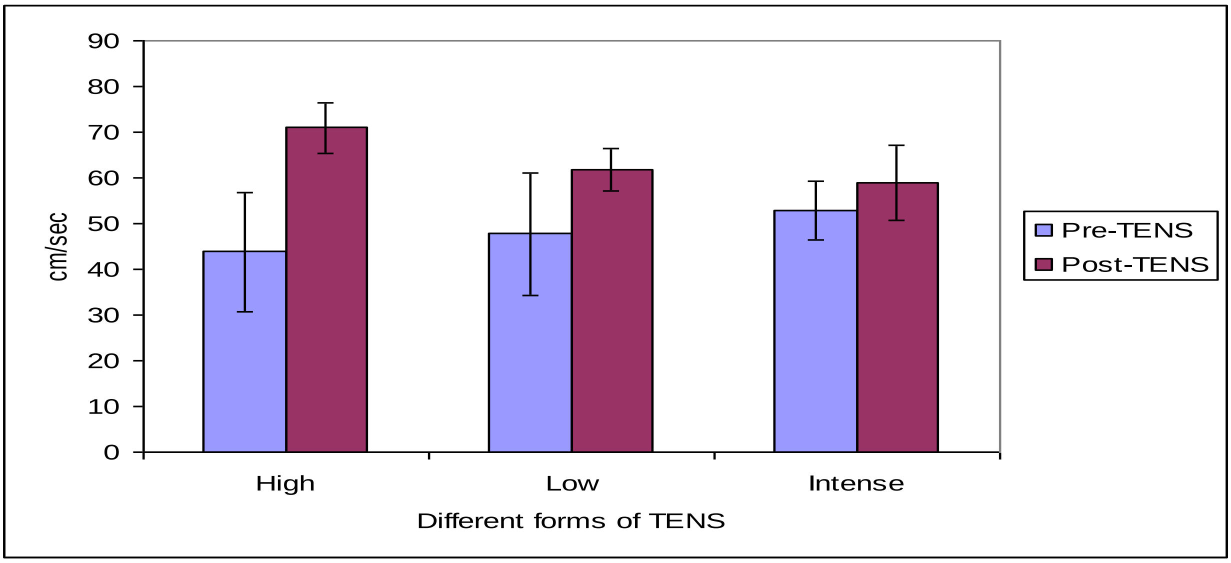

Fig. (3): Peak systolic velocity (cm/sec) of all studied groups for high, low, and intense TENS pre and post- TENS application.

Resistivity index (%)

Table (3) and figure (4) show the comparison of mean values of resistivity index of all studied groups. Before application of high TENS (100 pps, 80 µsec), the mean value of resistivity index was 0.92±0.017%. After application of high TENS, the mean value of resistivity index decreased significantly (0.81±0.04%). The percentage difference was -11.96% with t= -2.355 and p<0.034. The mean value of resistivity index for group II "low TENS" (2 pps - 200 µsec) was 0.94±0.051%. After application of low TENS, the mean value of resistivity index decreased significantly. Its value was 0.76±0.041 (t= 3.171 and p<0.007) with percentage difference of -19.15%. Group III "Intense TENS" (150 pps – 300 µsec) showed a mean value of resistivity index of 0.96±0.036 %. After application of intense TENS, the mean value (0.86±0.081%) decreased significantly. The mean difference was -10.42% with high significance level p<0.0001.

Table (3): *Statistical analysis of mean values of resistivity index (%) of all studied groups for high, low and intense TENS pre and post-treatment.*

	Group I		**Group II**		**Group III**	
	High TENS		**Low TENS**		**Intense TENS**	
	Pre-TENS	Post-TENS	Pre-TENS	Post-TENS	Pre-TENS	Post-TENS
Mean	0.92	0.81	0.94	0.76	0.96	0.86
SD	0.017	0.04	0.051	0.041	0.036	0.081
% Difference		-11.96%		-19.15%		-10.42%
t-value		2.355		3.171		6.597
p		0.034		0.007		0.0001
Significance		S		HS		HS

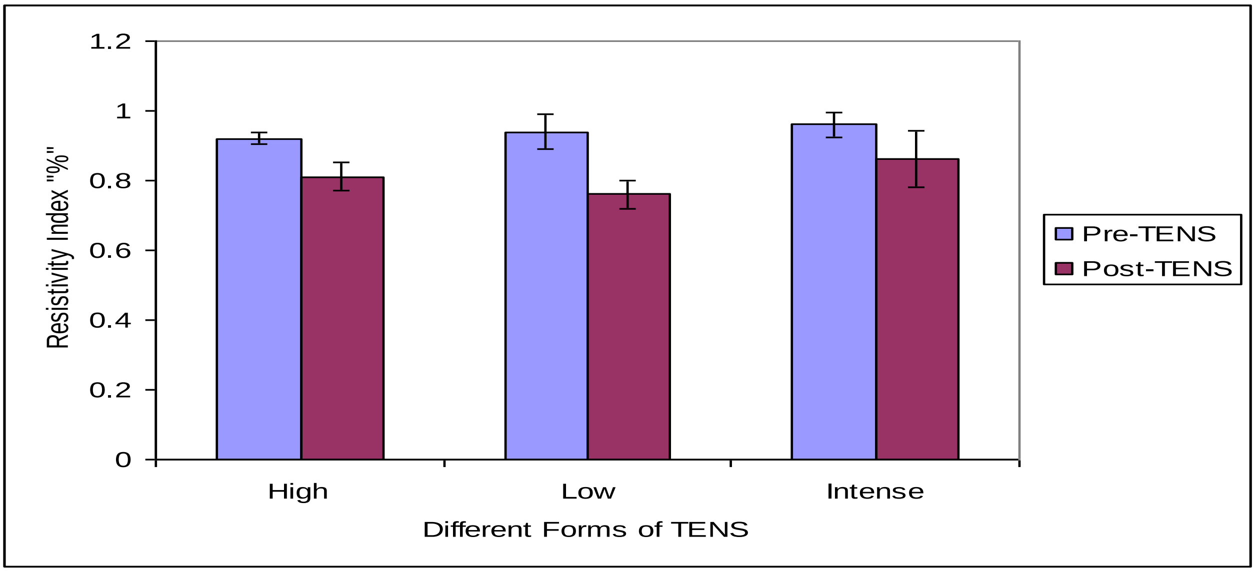

Fig. (4): Resistivity index (%) of all studied groups for high, low and intense TENS pre and post- TENS application.

DISCUSSION

The results of this study indicated that there was a highly significant increase of blood flow after application of low TENS (44.74%) when compared with other studied groups, (37.41% for high TENS and 32.11% for intense TENS). Peak systolic volume showed high significant increase after application of high TENS (62.06%) when compared with other studied groups (29.35% for low TENS and 11.41% for intense TENS). In addition, there was a significant decrease of resistivity index after application of low TENS (-19.15%) when compared with other studied groups (-11.96% for High TENS and -10.42% for intense TENS).

From the mentioned results and bases of literature, one can observe that the effect of TENS on vascular system depends on stimulation intensity and frequency that, when intensity is sufficient to cause muscle contraction, there wasa transient local increase in blood flow. This is in agreement with the reports of previous studies and revealed that when TENS is applied to the peripheral nerves for 20-30 minutes, it could produce a significant increase in blood flow and peak systolic velocity and significant increase in resistivity. These findings may be attributed to stimulation efferent fibers with intensity at motor level producing muscle contraction[4].

In addition, TENS increases both skin temperature and skin blood flow in subjects with no known pathology and in patients with chronic leg ulcers. The mechanism underlying their results was difficult to ascertain[1].

Cram et al. (2002)[2] showed the effect of TENS intensity on local and distal cutaneous blood flow, skin temperature, and found that low frequency TENS applied above the motor threshold increases local cutaneous blood flow. Nevertheless, there was no significance difference between groups for skin temperature[2]. Miller et al. (2000)[8] studied the difference in circulatory responses to voluntary and electrically muscle contractions. They found that the vascular changes induced by voluntary and electrically muscle contractions were similar in magnitude but different in duration.

Conclusion

The effect of TENS on circulation depends on stimulation intensity and frequency. When the intensity was sufficient to cause a moderate muscle contraction a transient local increase in blood flow occurred. These findings may be attributed to stimulation of efferent fibers with intensity at motor level producing muscle contraction.

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الملخص العربي

إستجابة الأوعية الدموية الجزئية للأشكال المختلفة لجهاز تنبيه العصب الكهربى عبر الجلد

يعتبر جهاز التنبيه الكهربي للعصب عبر الجلد وسيلة للتحكم فى الألم. وقد وجد له تأثير على استجابة الأوعية الدموية وذلك بزيادة تدفق الدم فيها وتقليل مقاومة الشرايين فى الأشخاص الأصحاء. ومع هذه الدراسات المتعددة لم تتم المقارنة بين أنواع الأشكال المختلفة لموجات جهاز التنبيه الكهربي للعصب عبر الجلد. **الهدف:** يهدف هذا البحث إلى دراسة تأثير الاشكال المختلفة للتنبيه الكهربائى العصبى عبر الجلد على إستجابة الأوعية الدموية للأشخاص الاصحاء من خلال قياس سرعة سريان وحجم الدم عبر الشرايين وشدة مقاومة الدم أثناء سريانه. وقد أجريت هذه الرسالة عملياً فى القصر العينى جامعة القاهرة. **الطريقة:** وقد تم اجراء هذا البحث على خمسة وأربعون فرداً ذكراً طبيعيين من طلبة كلية العلاج الطبيعي، جامعة القاهرة، وكانوا خاليين من الأمراض التى تصيب الجهاز الدموى ومتوسط أعمارهم 18.92±1.5 سنة ومتوسط أوزانهم 72.9±6.7 كجم ومتوسط أطوالهم 174±3.2 سم وقد تم تقسيمهم عشوائيا الى ثلاث مجموعات متساوية عدد كل مجموعة خمسة عشر شخصاً. المجموعة الأولى: تحتوى على 15 ذكر طبيعيين وينبه العصب القصبى للرجل اليسرى واليمنى بالتنبيه الكهربى العصبى عبر الجلد ذو التردد العالى (100 هرتز) لمدة 20 دقيقة ويقاس حجم وسرعة سريان الدم وشدة مقاومته أثناء سريان فى الشرايين قبل وبعد التنبيه مباشرة. المجموعة الثانية: تحتوى على 15 ذكر طبيعيين وينبه العصب القصبى للرجل اليسرى واليمنى بالتنبيه الكهربى العصبى عبر الجلد ذو التردد المنخفض (2 هرتز) لمدة 20 دقيقة ويقاس حجم وسرعة سريان الدم وشدة مقاومته أثناء سريانه فى الشرايين قبل وبعد التنبيه مباشرة. المجموعة الثالثة: تحتوى على 15 ذكر طبعيين وينبه العصب القصبى للرجل اليسرى واليمنى بالتنبيه الكهربى العصبى عبر الجلد ذو التردد الشديد (150 هرتز) لمدة 20 دقيقة ويقاس حجم وسرعة سريان الدم وشدة مقاومته أثناء سريانه فى الشرايين قبل وبعد التنبيه مباشرة. وتم قياس تدفق الدم بجهاز الموجات الصوتية المزدوج. **النتائج:** أظهرت النتائج وجود زيادة ذو دلالة إحصائية فى سرعة سريان الدم وتدفقه وخاصة بعد التنبيه ذو التردد المنخفض. وجود نقص ذو دلالة إحصائية فى مقاومة الدم عند نهاية الشرايين بعد التنبيه ذو التردد العالى. وجود فروق ذات دلالة إحصائية بين استخدام التنبيه الكهربى العصبى عبر الجلد ذو التردد العالى والتردد المنخفض. ولم توجد فروق ذات دلالة إحصائية بين استخدام التنبيه الكهربى العصبى عبر الجلد ذو التردد العالى والتردد الشديد. وقد زاد سرعة الدم وحجمه فى المجموعة الأولى بنسبة 37.41% بينما زاد فى المجموعة الثانية بنسبة 44.74% وقد زاد فى المجموعة الثالثة بنسبة 32.11%. بينما قلت المقاومة فى المجموعة الأولى بنسبة – 11.96% وفى المجموعة الثانية بنسبة – 19.15% وأخيرا فى المجموعة الثالثة بنسبة –10.42%. **الخلاصة:** يعتمد تأثير جهاز التنبيه الكهربي للعصب عبر الجلد على قوة التنبيه وكذلك التردد المستخدم. عندما يكون التنبيه كاف لإحداث انقباض عضلى فإن سرعة تدفق الدم تزيد تباعاً. ومن الممكن رجوع هذه النتائج لتنبيه الأعصاب الخاصة بالعضلات واحداثها انقباض للعضلات اتى على أثره سرعة تدفق الدم وتقليل مقاومة الشرايين.

الكلمات الدالة: جهاز التنبيه الكهربي للعصب عبر الجلد ، تدفق الدم ، نغمة الأعصاب السيمبثاوية .