# Sex and age differences in sensory threshold for transcutaneous electrical stimulation

*Diferenças de sexo e idade no limiar sensitivo para estimulação elétrica transcutânea*

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## Abstract

**Introduction:** Pain is one of the main symptoms prevalent in most pathologies. Transcutaneous Electrical Nerve Stimulation (TENS) represents not only a therapeutic measure, but also a mean to quantify the neurosensory and pain perception in patients with chronic pain. **Objective:** To evaluate the relationship between sex and age with neurosensory thresholds (sensory threshold and tolerance threshold) in the application of therapeutic current in patients with chronic pain. **Methods:** Forty-five patients with chronic pain (30 women and 15 men) aged between 24 and 87 years were selected. Each patient answered the Individual Questionnaire, McGill Pain Questionnaire (MPQ) and Beck Depression Inventory (BDI). Subsequently, the electric current was applied, through which the sensory and pain thresholds were analyzed, as well as the perception of activation of the neurosensory pathways for each individual. Data were analyzed using the SPSS 24.0 for Windows. **Results:** There was no significant correlation ($p > 0.05$) between a possible depressive diagnosis and the perception of current by the sensory and pain thresholds. Regarding sex, there was a significant difference in sensory thresholds ($p = 0.003$) between men and women, while no statistical differences were observed between sexes for pain complaint and pain threshold ($p > 0.05$). For the correlational analysis, a significant correlation ($p = 0.05$) was identified between the variables BMI and pain tolerance threshold ($r = 0.68$) for females and age and sensory threshold ($r = 0.65$) for males. **Conclusion:** The sex and age variables are important in the measurement of TENS parameters because they lead to significant differences in sensory and pain thresholds.

**Keywords:** Acute pain. Chronic pain. Pain threshold. Sensory threshold. Transcutaneous electric nerve stimulation.

## *Resumo*

***Introdução:*** *A dor é um dos principais sintomas prevalentes na maioria das patologias. A estimulação elétrica ervosa transcutânea (TENS) se apresenta não apenas como medida terapêutica, como também um meio de quantificar a percepção neurossensitiva e dolorosa em pacientes com dores crônicas.* ***Objetivo:*** *Avaliar a relação entre sexo e idade com os limiares neurossensitivos (limiar sensitivo e limiar de tolerância) na aplicação da corrente terapêutica TENS, em pacientes com dores crônicas.* ***Métodos:*** *Foram selecionados 45 pacientes com dores crônicas (30 mulheres), com idade entre 24 e 87 anos. Cada paciente respondeu ao Questionário Individual, ao Questionário McGill de Dor (MPQ) e ao Inventário de Depressão de Beck (BDI). Posteriormente, aplicou-se a corrente elétrica TENS, pela qual foram analisados o limiar sensitivo e doloroso, bem como a percepção de acionamento das vias neurossensitivas para cada indivíduo. Os dados foram analisados pelo pacote SPSS 24.0 for Windows.* ***Resultados:*** *Não houve correlação significativa (p > 0,05) entre possível diagnóstico depressivo e a percepção da corrente pelos limiares de sensibilidade e dor. Em relação ao sexo, houve diferença significativa nos limiares sensitivos (p = 0,003) entre homens e mulheres. Já para a queixa de dor e limiar de dor, não foram observadas diferenças estatísticas entre os sexos (p > 0,05). Para as análises correlacionais, identificou-se correlação significativa (p = 0,05) entre as variáveis de índice de massa corporal e limiar de tolerância à dor (r = 0,68) para o sexo feminino e idade e limiar sensitivo (r = 0,65) paro o sexo masculino.* ***Conclusão:*** *As diferenças identificadas entre os limiares de sensibilidade entre os sexos, onde as mulheres identificaram o estímulo elétrico significativamente primeiro que os homens, podem auxiliar nas doses de intensidade ou tipo de corrente terapêutica dos pacientes.*


***Palavras-chaves:*** *Dor aguda. Dor crônica. Limiar da dor. Limiar sensorial. Estimulação elétrica nervosa transcutânea.*

## Introduction

Pain can be understood as a state in which the person experiences unpleasant sensory and emotional sensations, which may or may not be associated with tissue damage.[1,2] Its impact is extensive, since it corresponds to 40% of the main complaints in health services of primary care.[3] According to Araújo and Romero,[4] although pain is one of the main symptoms prevalent in most diseases, its study by health professionals is scarce and sometimes underestimated.

When the pain exceeds three months with a certain constancy, it is classified as chronic.[5,6] This type of pain is complex and still requires further investigation of the pathophysiological mechanisms to improve existing treatments.[7] There is evidence of significant differences between the sexes in the prevalence of chronic pain and the neurobiology of pain.[8] It is extremely important to classify it by its duration, since each type of pain has its uniqueness in terms of biopsychosocial and physiological changes in the human body, which also guides the most appropriate treatment.[9]

Transcutaneous electrical nerve stimulation (TENS) is considered one of the most efficient non-drug therapeutic alternatives for the treatment of pain.[10,11] TENS is a low-cost electrotherapeutic treatment, widely used in physiotherapy for analgesia.[10,12] It is a low-voltage electrical current that transmits electrical signals to stimulate afferent sensory pathways. Its adjustment is made in the pulse frequency (Hz), in the pulse duration in microseconds (μs) and in the pulse intensity (mA), which will determine its therapeutic purpose.[13]

For acute pain, low-intensity, high-frequency TENS is indicated, which, through the gates theory,[14] closes the ascending nociceptive pathway, allowing only the electrical stimulus to be transmitted. For chronic pain, high intensities and low frequency are used, causing analgesia by releasing endogenous opioids, according to theory.[15] As for the adequate current amplitude, there is a variation according to the neurosensory threshold of each patient, in order to produce a sensation of individually perceived paresthesia and avoid accommodation.[16]

Thus, some authors describe TENS as an important tool in collecting information about the perception of these neurosensory thresholds in order to measure them.[10,12] Both the sensory threshold, which is the moment of sensory perception triggered by a small stimulus, and the pain threshold, in which the pain already begins to be perceived by a certain amount of energy, are moments usually used in the neurosensory assessment.[17]

Since data on sensory thresholds, including pain perception, are usually obtained subjectively through questionnaires and scales, electrical stimulation becomes not only a therapeutic alternative, but also a reliable

and regularly quantified method to analyze this sensory perception, since the analysis of the sensory pathways, as well as the nociceptive phenomena, are preponderant factors in the assessment and clinical performance of the physical therapists in the rehabilitation of diseases.[17]

One of the important factors for the treatment and assessment of the clinical response of pathologies that occur with pain is the identification of its pain perception threshold. TENS is a non-invasive electrotherapeutic resource, being effective in modulating chronic or acute pain. Although some studies have been designed to prove the effectiveness of TENS for pain,[1,3,4] there is still no consensus on the difference in initial neurosensory perception for each individual, which may vary according to the physiological particularities determined by sex.[6,8] Quantifying and qualifying the intensity in milliamps (mA) of the therapeutic current, and how these waves are perceived by patients, may help in the adequacy of electrotherapeutic treatment in future research.

Thus, the present study intends to assess the relationship between sex and age with neurosensory thresholds (sensory threshold and tolerance threshold), in the application of the TENS therapeutic current, in patients with chronic pain.

## Methods

This is a quasi-experimental study with convenience sampling. The study was previously approved by the Ethics Committee of the Euro Americana University Center (UNIEURO), under protocol number 3.353.560. All participants were informed about the study and signed the Informed Consent Form. The collection was carried out in a bright room at room temperature for 30 non-consecutive days.

To carry out the research, individuals with chronic pain, of both sexes, older than 18 years were included. Pregnant women, patients diagnosed with neoplasia, those who had undergone radiotherapy within a period of less than one year, patients with skin erosion in the painful region, diagnosis of epilepsy, low ability to understand commands, diagnosis of peripheral neuropathies associated with hyperesthesia or hypoesthesia or neurological diseases were excluded of the study.

Initially, the patients responded to an anamnesis, with the aim of identifying general health conditions and some information that could be applied to the exclusion criteria. Subsequently, the Beck Depression Inventory (BDI)[18] was applied to identify possible indications of depressive psychological alteration and, at the end of the same day, the McGill Pain Questionnaire (MPQ)[19] was applied to identify the subjective conditions of the magnitudes of pain for each patient.

The application of the current was carried out immediately after the questionnaires were solved. Patients were positioned seated in a chair with the right arm in slight extension and supination on a table. The lower limbs remained flexed at a 90° angle and the feet touching the ground. The Neurodyn® II device (IBRAMED Ins. Ltd.) was used with four channels, one channel with two silicon carbon electrodes covered with conductive gel and fixed with microporous tape to the skin of the forearm. The first electrode was positioned 2 cm away from the pulse joint line and the second 10 cm away from the first electrode. For all patients, the conventional mode of TENS was used, with a quadratic, symmetrical and biphasic wave, with a frequency of 100 Hz and a pulse width of 100 μs.

To define the sensory threshold, the electrical impulse was then initiated, so that the current amplitude was gradually increased (3s/mA) until the individual reported the first perception of the electrical stimulus. To identify the pain tolerance threshold, the stimulus progressed until the patient reported discomfort. Then the electrodes were repositioned to the participant's painful area and the current remained on for 20 minutes to obtain analgesia.

For the statistical analysis, the SPSS 24.0 package for Windows was used. The normality of the sample distribution was verified using the Shapiro-Wilk test. Results referring to continuous variables were expressed as mean and standard deviation; scalar values were expressed as median and interquartile range. Data for categorical variables were presented by absolute and/or relative frequency. As a hypothesis test, the Mann-Whitney test was chosen and as a correlational test, the Spearman test. The present study assumed that p values $\leq 0.05$ would indicate statistical differences.

## Results

Forty-five participants with chronic pain complaints were assessed, 30 women and 15 men. All participants met the inclusion criteria and no assessed patient was excluded from the study.

The total sample had a mean age of 51.10 ± 16.97 years. For women, the mean age was 50.36 ± 16.68 years and for men, 54.28 ± 17.53 years (p = 0.68). The body mass index (BMI) had a mean of 27.16 ± 5.32 kg/m² (female: 27.39 ± 6.06 kg/m²; male: 26.71 ± 3.64 kg/m²; p = 0.84), where 75% of the sample showed changes in body composition, at least with overweight (BMI ≥ 25 kg/m²). The sample characteristics related to sensory, tolerance and levels of pain and depression are shown in Table 1.

Figure 1 presents the values found in relation to the application of currents and the previous perception of pain. It is observed that men presented a sensory threshold 41.4% higher than that of women. As for the pain threshold, these values decrease to 4.76%.

Correlational analyses showed significance (p ≤ 0.05) in different ways for both sexes in relation to sensory thresholds, electrical stimulation and pain tolerability, as shown in Figure 2. Regarding the BDI, of the total sample, 44.44% had possible depression associated with pain, of which 15 were women and 4 were men. There was no significant correlation between the possible diagnosis of depression and the perception of current by the thresholds of tolerance and sensory (p > 0.05).

**Table 1** - Neurosensory characteristics and depression score of the sample (n = 45)

| | Mean ± standard deviation | Minimum | Maximum |
|---|---|---|---|
| Sensory threshold (mA) | 15.61 ± 5.93 | 8.00 | 36.00 |
| Tolerance threshold (mA) | 45.30 ± 17.64 | 17.00 | 95.00 |
| Pain (score) | 12.64 ± 7.38 | 2.00 | 41.00 |
| Depression (score) | 9.75 ± 6.60 | 1.00 | 29.00 |

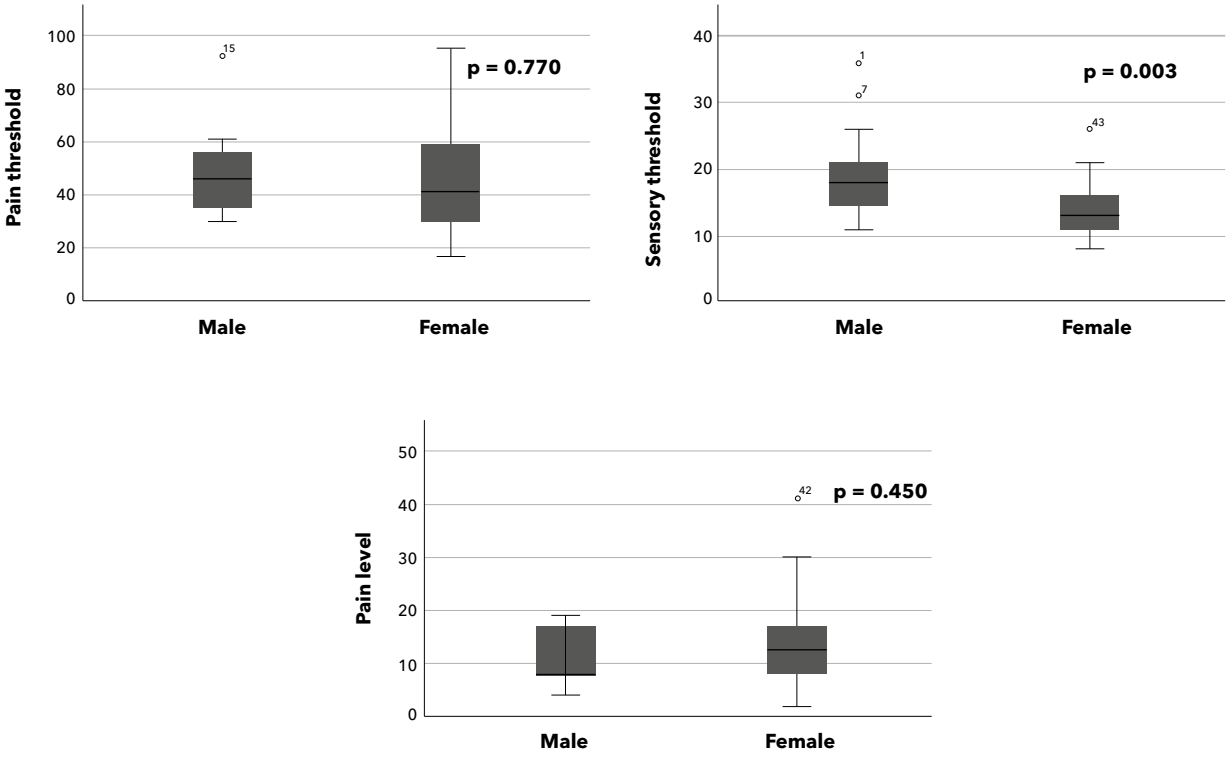


**Figure 1** - - Comparison of the parameters of sensibility and tolerance to electrical current (TENS) and initial conditions of the pain condition between males and females.

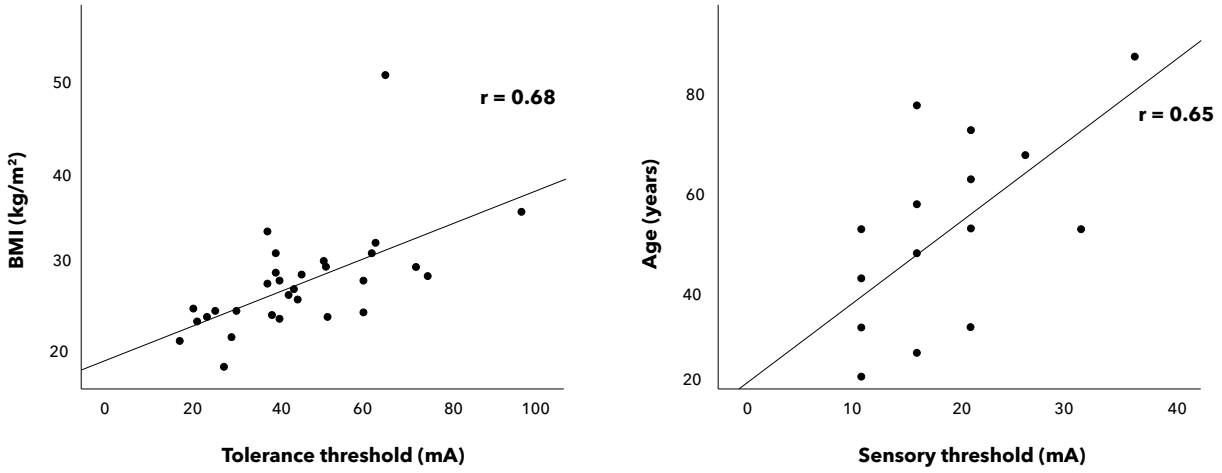


**Figure 2** - Correlation between body mass index (BMI) and electrical current tolerability threshold presented by females, and correlation between age and sensory threshold presented by males.

## Discussion

The predominance of female participants was expected, since studies show the prevalence of chronic pain in women.[20-22] In the study of Vasconcelos e Araújo,[20] 84.60% of women and 16.4% of men sought health care services for the reduction of chronic pain.

The comparison between the sexes showed a significant difference (p = 0.003) for the sensory threshold, with females having a mean of 13.77 ± 4.16 mA and males of 19.57 ± 7.27 mA. Several studies[23-26] corroborate this finding, pointing out that women had a lower sensory threshold than men, where several conditions inherent to anatomical and physiological discrepancies, such as the size of the neuromotor course and amounts of neurotransmitters, can generate these differences in sensory response time.

As for the correlation of thresholds with the age variable, it was found that male patients had a positive and strong correlation ($r^2$ = 0.646; p = 0.009), indicating that the younger the patient, the lower the intensity of the current needed to recruit the sensory pathways, and demonstrating changes in the sensory system of older men. Rocha et al.,[17] applied low frequency TENS (20 HZ) in groups of men and women and observed that the basal sensory threshold increased significantly for men, but not for women, after skin warming. One hypothesis for this correlation is that observed by Gøransson et al.[27] in a study on the density of epidermal nerve fibers, where a significant decrease in the amount of fibers was found in older and male individuals. As for Guirro et al.,[23] the phenomenon of reduced sensory to electrical stimuli was identified for both sexes.

This decline in sensory responses in the elderly may be a result of the brain aging process, which seeks to compensate for deficient functions with complex mechanisms of inhibition and excitation in somatosensory processing.[28] Another study reported that there is an association between increased sensory threshold and degeneration of sensory nerves and reduced metabolism, due to the entry of the organism from the period of senescence.[29]

Regarding BMI, the results showed a significant moderate correlation with the current tolerance threshold only in women ($r^2$ = 0.677; p < 0.001). In the study by Maffiuletti et al.,[30] obese individuals had lower excitability (higher thresholds) than non-obese peers, corroborating the findings of the present study in which obese women had a lower sensory threshold when compared to men.

Despite the BMI in both sexes having a similar mean (men: 26.71 ± 3.64 kg/m²; women: 27.39 ± 6.06 kg/m²), the correlation with the tolerance threshold was significant only in women. Thus, the study identified the need for a segmented analysis of body composition. Petrofsky et al.[31] analyzed the interference of subcutaneous fat

density and blood flow as factors that interfere in the perception of current for muscle contraction. Mariani et al.[32] showed that the differences between the %G between men and women are directly related to the pain threshold. Seno et al.[26] hypothesized hormonal and psychological influences, subcutaneous fat, muscle size, brain functioning and associated comorbidities. Schopper et al.,[33] in a study with patients with chronic pain, observed that differences in pain tolerance between men and women can be directly influenced by intrinsic and sociocultural factors.

Although the results of the present study do not demonstrate a correlation between depression and neurosensory thresholds, it is important to highlight the growing relationship of coexistence between chronic pain and depressive disorder.[34] Adler et al.[35] observed that patients diagnosed with depression had alterations in the threshold of somatosensory perception, with a reduction in the threshold of pain perception. Kato et al.,[36] using a quantitative sensory test with electrical stimulation, found that patients with chronic pain showed greater sensitivity when diagnosed with associated psychological characteristics. On the other hand, Kivrak et al.[37] observed that anxiety is a predictor of pain, but that depression did not indicate an influence on nociceptive perception.

## Conclusion

The study showed a higher frequency in the search for health services for the treatment of chronic pain by females. It should be noted that there is a significant difference between the sexes in relation to the sensory threshold, where women showed lower perceived values of the applied TENS therapeutic current than men. The sensory threshold also showed a significant correlation for men in relation to age, demonstrating that over the years there is a reduction in the speed of the sensory response with an increase in the threshold. Females, on the other hand, showed a positive correlation between BMI and pain tolerance threshold.

It was not possible to observe the influence of depression on neurosensory threshold responses. Although there are still gaps in the scientific literature in the definition of parameters for the various forms of electrotherapy, the present study showed that the difference between the sexes and the influence of some individual variables can interfere with the perception of neurosensory thresholds. Thus, further studies are needed to specifically and in detail control the body composition, behavioral and psychological assessment of the participants.

## Authors' contribution

LHAS was responsible for writing the text and, together with LSV, for tabulating the data. LCP was responsible for reviewing the manuscript and analyzing the data; RJRMC, for curating the data and supervising the procedures performed; and DRH, for designing the project, supervising and final review. All authors approved the final version.

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