ABSTRACT

Objectives: To qualitatively and quantitatively analyze the interaction of Russian and Aussie currents in isometric contraction of the quadriceps femoris muscle in the sensory, motor and pain tolerance spectra in healthy young women. Methods: The subjects were studied at a single point in time. A lower limb was selected at random to receive each current, and the electrodes were placed simultaneously on both legs, respecting 10 minutes between individual stimulation. Sensory, motor and pain-tolerance thresholds were assessed in quantitative (current density in mA/cm²) and qualitative (VAS) terms. Results: Subjects were 19 volunteers, aged 22.31 (1.29), with a BMI of 21.79 (1.78). The Aussie current reached the sensory threshold with significantly lower current density when compared with the Russian current for the same threshold. The results were significant in the overall group (treatment) for the two currents studied in terms of current density needed to reach the three thresholds. However, in the blocks (individually), there was significance only for the sensory threshold (p = 0.0126). Analysis of the perception of discomfort, assessed by VAS, was significant at the three time points for both currents, but in the comparison between these there was no significant difference. Conclusion: The Russian and Aussie currents are adequate in terms of the current density required to reach each threshold studied, and present differences between one another during interaction with the biological system, with the Aussie current necessitating less energy. However, in terms of perception of discomfort there are no significant differences between the two currents. Level of evidence III; Therapeutic studies - Investigating the results of treatment.

Keywords: Electric stimulation therapy; Muscle strength; Quadriceps muscle; Medium current frequency; Physical therapy modalities.
Descriptores: Terapia por estimulación eléctrica; Fuerza muscular; Músculo cuádriceps; Modalidades de fisioterapia.

INTRODUCTION

Neuromuscular Electrical Stimulation (NMES) comprises the electrical currents that aim to promote muscular tetanization through the activation of action potentials in the motoneurons, based on the electrical stimulation of their intramuscular branches. These stimulations have been widely used for more than 40 years in rehabilitation, beauty and fitness.

Muscle contraction may occur on a voluntary basis, through the action potential of the motor cortex, or induced by peripheral electrical stimulation. In voluntary muscle contraction, the smaller motor units, primarily composed of Type I fibers (slow-fatigue-resistant contraction) are recruited first. During muscle electrical stimulation, an inversion occurs. Type II fibers (fast, easily fatigable contraction) are recruited first, since the motor nerves of Type II fibers are larger than those of Type I fibers, having lower resistance to electric current.

The skin serves as a capacitive barrier to the flow of electric current. As the frequency of the applied current increases, the skin presents progressively smaller impedance. At the kilohertz level (2000 to 4000 Hz), impedance is very low, dissipating less electrical energy in the epidermis and a greater proportion of electrical energy is available to stimulate the underlying tissue, allowing the stimulation of motor nerves. However, the motor nerves do not respond to frequencies in the kilohertz range, requiring their modulation in low-frequency ranges. Increased currents are recruited first. During muscle electrical stimulation, an inversion of action potentials in the motoneurons, based on the electrical stimulation of their intramuscular branches, become stronger.

Frequency, pulse duration and especially the intensity of electric current are necessary for a good result of muscular strengthening. Different individuals have different thresholds, presenting multiple subjective sensations, becoming an important subject of study and analysis. The development of a methodology to analyze the subjective-objective relationship presented by the individual submitted to such currents is of paramount importance to understand the variables involved. Qualitatively measuring the intensity of the electric current interpreted by the patient as comfortable or not, and their quantitative measurement, are necessary for using more receptive electrotherapeutic resources in clinical practice.

It is believed that although high intensities promote greater recruitment of motor units, they can generate greater discomfort during electrostimulation as it can recruit nociceptors. Increased currents are a relevant point for recruitment, but if recruitment is carried out with lower levels of current, this may be more interesting as it does the same work with lower energy levels. Therefore, we aim to qualitatively and quantitatively analyze the application of the Russian and Aussie currents in the isometric contraction of the femoral quadriceps muscle, from a sensory and motor perspective, and considering discomfort in healthy young women.

METHOD

This is a quasi-experimental paired cross-sectional single-blind study, in which 44 volunteers were recruited for convenience through verbal invitation. Recruitment began upon approval of the Research Ethics Committee (CEP) of UFPE, under CAAE number 426286151.0000.5208. Collection occurred from 27/04/2015 to 10/06/2015 with each volunteer followed once. Acceptance for the experiment was ensured by reading and signing an Informed Consent (IC). The study included 19 volunteers characterized by age, in the age group of 22.31 (1.29), and BMI in the range of 21.79 (1.78). The sample was made up into a flowchart (Figure 1).

Participants included in the study: women aged 18 to 25 with BMI (Body Mass Index) within normal range, self-reported as healthy. The study did not include the volunteers who reported pain promoted by any previous pathological condition, cardiopathy, type 1 and 2 diabetes, circulatory disorders in the lower limbs, allergy to electrical stimulation or superficial sensitivity in the area to be stimulated, with pre-menstrual tension, menstruation or pregnancy, and any contraindications to electric current (cardiac pacemaker, intrauterine device — IUD —, metal rods in the femur etc.).

Collection procedure

The volunteers were chosen by draw, by Simple Casual Sample (using papers for the limbs and currents) to determine which lower limb would start the experiment and its concomitant current. The papers drawn were given to the researcher, who were not informed of the draw results, characterizing the study's single-blind design.

The experiment was performed with the volunteers in dorsal decubitus position with lower limbs extended. Before starting the experiment, voluntary isometric contraction of the femoral quadriceps was requested so that the moment of isometric tetanization was more easily identified by the evaluator (visually) and by the volunteer herself during electrostimulation.

The electrodes were placed in both lower limbs, simultaneously. Placement of a canal with two electrodes (42.98 cm each) arranged in the rectus femoris muscle was based on the measurement of this muscle from the antero superior iliac crest up to the apex of the patella, with the lower limb extended. Once this measure was taken, its center value was adopted, in which the electrodes were placed 3 cm above and below this measurement. The other channel, with two electrodes, were arranged in the belly muscle of the vastus lateralis and another one in the belly muscle of the vastus medialis, for each limb. The electrodes were attached with gel, and were secured with the elastic bands from the electroestimulator itself.
A sensation of discomfort was determined after tetanization, by recording at which current intensity, through mA, the discomfort was referred by the volunteer as the maximum level of discomfort bearable, and which VAS graduation referred to that moment. The study had the following Independent Variables: Sine wave; area of the electrodes (42.98 cm²) (in which the standard factory electrodes were used for the research); measurement of electrical current density (mA/cm²); age group of volunteers; Body Mass Index (BMI). The Dependent Variables were: subjective and objective sensory perception of electric current; subjective and objective sensory perception of the muscle contraction promoted by the electric current; subjective and objective sensory perception of discomfort from the muscle contraction promoted by the electric current.

### Data analysis

The statistical program Biostat 1.0 was used. To determine the normality of quantitative data of milliamperage, the KS test (Kolmokorov-Smirnov with Lilliefors probability) was initially performed. The data presented normal distribution. The following central tendency measures were adopted for the parametric data: arithmetic mean, standard deviation, confidence interval and coefficient of variation. The data were submitted to one-way ANOVA, followed by the posthoc Student’s T test (LSD). The comparison between the sensory-sensory, motor-motor and discomfort-discomfort moments between the two currents were performed using the ANOVA T test for two dependent samples. In the analysis of data referring to the VAS scale, the Friedman test was used to compare the data of the sensory, motor and discomfort moments. The Wilcoxon test was used to compare the sensory-sensory, motor-motor and discomfort-discomfort moments. Data are presented with arithmetic mean and standard deviation for non-parametric (quantitative discrete) data (VAS analysis) were used. The significance level adopted in this study was p<0.05.

### RESULTS

Statistical significance was found for current densities (mA/cm²) between the Sensory, Motor and Discomfort thresholds for both currents (Aussie and Russian currents). (Figure 2)

In the comparison of mA/cm² between Aussie and Russian currents, it was found that the Aussie current presents lower significant electrical density in the groups (p treatment) on all studied thresholds. However, with respect to the comparison of the two currents for the same individual (p block) this is not the case, demonstrating significance only at the sensory threshold, but not between the motor and discomfort thresholds. (Table 1)

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**Figure 1.** Sample flowchart.

The device used was the Neurodyn 10 canais (IBRAMED®), adjusted for both currents in the synchronized mode, 3 s rise ramp times, 9 s stimulus (on) time, 4 s pulse decay time and 12 s no stimulus (off) time were set. For the stimulation with the Aussie current, the parameter used was a carrier frequency of 1000 Hz, modulated at 50 Hz and pulse duration of 2 ms. The Russian current was applied with the carrier frequency parameter of 2500 Hz, modulated at 50 Hz, with pulse duration of 10 ms. Between the stimulation of each lower limb, a 10-minute interval was observed.

Once the experiment was started, the current intensity was increased slowly by 1 to 1 milliampere (mA) until each threshold was reached. The sensory threshold was determined by the minimum intensity of applied current under which the volunteer reported the first perceived skin sensation (mild tingling). The quantitative measurement of this moment was properly recorded through mA, and qualitative evaluation was conducted using the Visual Analogue Scale (VAS), with which the volunteers evaluated their sensations (“0” indicates no sensation and “10” indicates the greatest sensation of discomfort they could bear).

The motor sensation evaluation was performed at the moment of isometric tetanization of the quadriceps femoral muscle by recording at which current intensity (mA) tetanization was obtained (visually perceived), and which VAS graduation corresponded to this moment. The sensation of discomfort was determined after tetanization, by recording
Table 2 presents the confidence intervals and the coefficient of variation, showing that the data are within their respective intervals and that the highest coefficient of variation, at its moment, was presented by the Russian current upon tetanization of the femoral quadriceps (36.31%) compared to the Aussie current (29.12%). (Table 2)

In terms of awareness of the sensation perceived by the individuals, measured by VAS at the sensory, motor and discomfort moments, the Friedman test (Table 3) showed significance between the thresholds for the two currents studied. The comparison, performed through the Wilcoxon test, between the sensory-motor moments resulted in p=0.015, motor-motor moment at p=0.17 and discomfort-discomfort at p=0.006, revealing that there is no significant difference between the Russian and Aussie currents regarding the sensation perceived by the volunteers studied.

Table 1. Comparison of Sensory, Motor and Discomfort thresholds of the volunteers doing the Aussie and Russian currents (mA/cm²).

<table>
<thead>
<tr>
<th></th>
<th>Aussie/Russian</th>
<th>Russian current</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory/Sensory</td>
<td>0.15 (0.06) / 0.25 (0.084)</td>
<td>0.07 (0.05) / 0.28 (0.092)</td>
<td>p=0.0001/p=0.06</td>
</tr>
<tr>
<td>Motor/Motor</td>
<td>0.75 (0.22) / 1.0 (0.36)</td>
<td>1.0 (0.38) / 1.0 (0.36)</td>
<td>p=0.0001/p=0.13</td>
</tr>
<tr>
<td>Discomfort/Discomfort</td>
<td>1.01 (0.32) / 1.28 (0.39)</td>
<td>2.97 (0.25) / 3.93 (0.39)</td>
<td>p=0.0001/p=0.06</td>
</tr>
</tbody>
</table>

*ANOVA Test for two dependent samples.

Table 2. Confidence interval and coefficient of variation of Sensory, Motor and Discomfort thresholds of volunteers doing the Aussie and Russian currents.

<table>
<thead>
<tr>
<th></th>
<th>Aussie current</th>
<th>Russian current</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence interval (CI)</td>
<td>Confidence interval (CI)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory - 0.15 (0.13-0.18)</td>
<td>Sensory - 0.25 (0.21-0.29)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor - 0.75 (0.64-0.85)</td>
<td>Motor - 1.0 (0.83-1.18)</td>
<td></td>
<td></td>
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<tr>
<td>Discomfort - 1.01 (0.86-1.16)</td>
<td>Discomfort - 1.28 (1.25-2.40)</td>
<td></td>
<td></td>
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<tr>
<td>Coefficient of variation</td>
<td>Coefficient of variation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensory - 35.88</td>
<td>Sensory - 34.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor - 29.12</td>
<td>Motor - 36.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Discomfort - 31.24</td>
<td>Discomfort - 30.06</td>
<td></td>
<td></td>
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</tbody>
</table>

Table 3. Data obtained from the VAS (Visual Analogue Scale) at the Sensory, Motor and Discomfort thresholds of the volunteers doing the Aussie and Russian currents.

<table>
<thead>
<tr>
<th></th>
<th>Aussie</th>
<th>Sensory</th>
<th>Motor</th>
<th>Discomfort</th>
<th>*Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum of Rankings</td>
<td>20.5</td>
<td>37</td>
<td>56.5</td>
<td></td>
<td>p=0.00001</td>
</tr>
<tr>
<td>Median</td>
<td>1</td>
<td>5</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean of Rankings</td>
<td>1.07</td>
<td>1.94</td>
<td>2.97</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Russian</th>
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<th>Motor</th>
<th>Discomfort</th>
<th>*Statistics</th>
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<td>8</td>
<td></td>
<td></td>
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<tr>
<td>Mean of Rankings</td>
<td>1.13</td>
<td>1.89</td>
<td>2.97</td>
<td></td>
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</table>

* Friedman test.

DISCUSSION

It is known that the perception of discomfort during electrostimulation is one of the limiting factors of its use in clinical practice, as to achieve some results it is necessary to increase current intensity, often not supported by the individual. This quasi-experimental study found that during electrical stimulation, both with the Russian and the Aussie currents, current intensity needs to increase significantly to reach each threshold (sensory, motor and discomfort). This fact provides certainty as to the perceived sensation, since a significant increase in the current intensity between each threshold is necessary until the moment of discomfort is reached.

It was found that the Aussie current requires lower electrical current density to reach the three thresholds measured compared to the Russian current. This means that for the Aussie current, it was possible to reach the thresholds at a lower intensity, thus allowing levels of muscle recruitment similar to those of the Russian current, using lower current intensity.

Considering the volunteers’ overall result, it was found that the Aussie current significantly presents sensory thresholds with less intensity than the Russian current. However, the motor and discomfort thresholds presented lower current intensity, but not significant compared to the Russian current.

At the sensitive threshold, the comparison between the two current produced significant general results (treatment) and block results, showing that at this threshold the currents are identified differently by the volunteers. Although the statistical block result was not significant, it tends to result in individual differences regarding the densities of the two currents required to promote a sensation of discomfort between the currents studied.

The coefficient of variation obtained during tetanization was higher for the Russian current compared to the Aussie current, implying that the milliampere fluctuates more during stimulation with the Russian current than with the Aussie current.

The VAS analysis showed that there is no significant difference in the perception of the two currents. However, comparing the discomfort-discomfort moment, although there is no significance, there is a tendency to be significant.

One study compared the torque and degree of discomfort produced by two forms of stimulation: low-frequency current and the Russian current, both applied at high intensity. Eighteen healthy young men participated, and it was concluded that between the two forms of NMES there are no differences in torque generation capacity and none of them is considered the most comfortable one.

Another study with 32 volunteers aged 19-55 compared 4 types of stimulation (Russian, Aussie, Pulsed Currents of 200 and 500 μs) for pulse duration, torque production and discomfort, reaching the conclusion that alternating currents (Russian and Aussie currents) are more comfortable according to these, the Aussie current promotes greater strength with less discomfort and is better accepted in clinical practice. However, the methodology differs from that of this study, as it determined the result of discomfort through verbal reporting.

Another study compared the level of discomfort between low- and medium-frequency currents (Aussie and Russian current) in the electrostimulation of the quadriceps femoris muscle in 45 healthy volunteers aged 18 to 30. Discomfort was evaluated by the Visual Analogue Scale and concluded that there were no differences regarding the sensory discomfort promoted by the currents, being closer to the results obtained in this study both with regard to the characteristics of the sample and the instrument used to measure discomfort, but it did not study the density of the currents used.

The limitations of this study included the small sample size (n=19) and was limited to healthy young women, making the findings limited and with external validity restricted to the group studied. It has been found that some results have come closer to significance, as in the case of mA/cm² between the blocks in the analysis of discomfort — discomfort and in the analysis of VAS at the threshold of discomfort-discomfort, between the currents. With a bigger sample, these results can be better defined.

Convenience sampling is another limitation of the experiment, and the study is reproducible only in samples equivalent to those used by this study.

There are few studies in the literature comparing the Aussie and Russian currents, and these are empirical, linked to websites for the sale of currents or from individuals that have a direct link with the creation of the Aussie current, therefore they should be analyzed with caution. Besides this, these citations are weak in the methodology of existing studies, such as randomizations and blinding, inclusion/exclusion criteria, heterogeneity of existing protocols, characteristics of the electrodes used, etc.
CONCLUSION

This study has found that the Russian and Aussie currents present differences between each other during interaction with the biological system, through the mA/cm², where the Aussie current requires less energy to reach the sensitive threshold compared to the Russian current. However, in terms of perception of discomfort, through the VAS, there are no significant differences between the two currents studied.

All authors declare no potential conflict of interest related to this article.

AUTHORS’ CONTRIBUTIONS: Each author made significant individual contributions to this manuscript. EJNPM (0000-0001-8680-180X)* and KVS (0000-0002-2026-7891)* collaborated in the literature search and final revision of the manuscript. *ORCID (Open Researcher and Contributor ID).

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