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Effects of cathode and anode of the direct current on changes in palmar grip strength: assessment through a dynamometry

Efeitos da cátodo e anodo de corrente direta em força de preensão manual: avaliação por meio de dinamometria

Efectos del cátodo y del ánodo de la corriente directa en los cambios de fuerza de prensión palmar: valoración a través de dinamometría

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ABSTRACT | This study objective is to investigate the polar effects of the direct current on muscular strength, evaluated by the manual dynamometer. The values of muscle strength, in kilograms, were compared before and after the procedure in the 3 groups (Anode, Cathode and Control). The project is a controlled randomized clinical trial, which was performed at the Laboratory of Physiotherapy of the University Andrés Bello (Physioterpy Carrer) with 150 healthy voluntary participants. The intervention consisted on the application of a direct current session with intensity of 2mA for 12 minutes, with an electrode of 48cm^2 (dose of 24mA×min and current density of 0.04mA/cm^2). The difference between the groups was in the stimulus with the cathode or the anode, and the application of the current was performed after the initial dynamometric evaluation. The main measured variable was the difference of maximum force of palmar grip (Kg), which was obtained through the difference between the best value of maximum pre-intervention force and the best value of maximum post-intervention force. The results indicate that there were no statistically significant changes in the intervention groups (p value=0.88) when comparing the maximum strength differences (FMdif). However, a slight improvement in strength was observed when comparing the groups only considering men from the cathode group (p value=0.94), and a slight decrease when comparing only women from the anode group (p value=0.91). It was concluded that, apparently, the direct current would not generate greater changes in the force of manual grasp after an intervention session on the forearm. Nevertheless, there are positive variations of strength in men from the cathode group, and negative ones in women from the anode group when analyzed independently, although these modifications are not statistically significant.

Keywords | Randomized Controlled Trial; Hand Strength; Electric Stimulation Therapy.

RESUMO | O objetivo deste estudo é pesquisar os efeitos polares da corrente direta sobre a força muscular, avaliada a partir do uso do dinamômetro manual. Os valores da força muscular, em quilogramas, foram comparados, antes e após o procedimento, nos 3 grupos (Ânodo, Cátodo e Controle). O projeto é um ensaio clínico randomizado controlado, desenvolvido no Laboratório de Fisioterapia da Universidade Andrés Bello (Faculdade de Cinesiologia), e do qual participaram 150 voluntários saudáveis. A intervenção consistiu na aplicação de uma sessão de corrente contínua a 2mA por 12 minutos, com um eletrodo de 48cm^2 (dose de 24mA×min e densidade de corrente 0.04mA/cm^2). A diferença entre os grupos estava no estímulo com o cátodo ou ânodo, e a aplicação da corrente foi realizada após a avaliação dinamométrica inicial. A principal variável medida foi a diferença de força máxima

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de aperto palmar (Kg), obtido a partir da diferença do melhor valor da força máxima de pré-intervenção e do melhor valor da força máxima pós-intervenção. Os resultados apontaram que não houve alterações estatisticamente significativas nos grupos de intervenção (p valor=0,88) ao se comparar as diferenças máximas de resistência (FMdif). No entanto, observou-se uma ligeira melhora na força ao se comparar os grupos apenas considerando os homens do grupo do cátodo (p valor=0,94 e uma pequena diminuição ao se comparar apenas as mulheres do grupo do ânodo (p valor=0,91). Concluiu-se que, aparentemente, a corrente direta não geraria maiores mudanças na força do aperto manual após uma sessão de intervenção no antebraço. No entanto, existem variações positivas de força em homens do grupo do cátodo e negativas em mulheres do grupo do ânodo, quando analisadas de forma independente, embora não sejam estatisticamente significativas.
Descritores | Ensaio Controlado Aleatório; Força da Mão; Terapia de Estimulação Elétrica.

RESUMEN | El objetivo de este trabajo es investigar los efectos polares de la corriente directa sobre la fuerza muscular, evaluada con dinamómetro manual. Los valores de la fuerza muscular en kilogramos fueron comparados antes y después del procedimiento en 3 grupos (Anodo, Catodo y Control). El diseño es Ensayo Clínico Aleatorio controlado. La investigación se realizó el Laboratorio de Fisioterapia de la Universidad Andrés Bello (Escuela de Kinesiología Santiago). El estudio se llevó a cabo con ciento cincuenta participantes voluntarios sanos. La intervención consistió en la aplicación de una sesión de corriente directa a una intensidad de 2mA por 12 minutos con un electrodo de 48cm^2 (dosis 24mA.min y densidad de corriente 0,04mA/cm^2). La diferencia entre los grupos radicaba en la estimulación con el cátodo o ánodo. La aplicación de la corriente se realizaba luego de la evaluación dinamométrica inicial. Cómo *outcome* principal se estimó la diferencia de Fuerza Máxima de prensión palmar (Kg). Esta se obtuvo de la diferencia del mejor valor de fuerza máxima pre intervención con el mejor valor de fuerza máxima post intervención. Los resultados indican que no existen cambios estadísticamente significativos en los grupos intervenidos (p valor = 0,88) al comparar las diferencias de fuerzas máximas (FMdif). Sin embargo, se aprecia una mínima mejora de la fuerza al comparar los grupos sólo considerando hombres del grupo cátodo (p valor = 0,94, y leve disminución al comparar sólo para mujeres del grupo ánodo (p valor = 0,91). Cómo conclusión se destaca que aparentemente la corriente directa no generaría mayores cambios en la fuerza de prensión manual luego de una sesión de intervención sobre el antebrazo. Sin embargo, existen variaciones positivas de fuerza en hombres del grupo cátodo y negativas mujeres del grupo ánodo al analizarlos independientemente, aunque estas modificaciones no resultan estadísticamente significativas.
Palabras clave | Ensayo Clínico Controlado Aleatorio; Fuerza de la Mano; Terapia por Estimulación Eléctrica.

INTRODUCTION

Electrical stimulation in physical therapy nowadays has a broad range of clinical applications, including muscle strengthening, pain control, management of edema, control of inflammation after an injury or surgical intervention[1]. Currently, electrotherapy offers a broad range of therapeutic possibilities, although clinically, the use of only a few currents has been privileged, leaving many modalities relegated to a minimum or no use. Despite this, in electrotherapy, a broad range of therapeutic currents continues to be offered to the groups, many of them little explored, a situation that limits the use of our resources in electrotherapy. One of the classic currents described in electrotherapy is direct current (DC) or galvanic (galvanism), the one that stands out for its particular physiological effects and that are not achieved with other modalities of currents[2]. Within these effects those activators are described (achieved with the cathode) or suppressors (anode) of nervous system activity, which could be useful therapeutically in different clinical conditions involving neuromuscular disorders[1,2]. The DC is a current that works with a constant intensity and with treatment times between 10 to 15 minutes. Unlike other electrical modes, in it only the parameters of current intensity and time are adjusted. Many physiotherapists are not completely proponents about the use of this current because they do not identify it as safe, due to the fact that within its potential risks the possibility of generating electrochemical burns stands out (acid or basic burns depending on the electrode) when the procedure is improperly applied. This is why this method must be worked under safety regulations and with current densities no higher than 0,2mA/cm^2 minimizing the risk (by recommendation of the literature) and adverse effects of galvanism[2].

The documentation of direct current in relation to its polar effects is scarce and old, and general, most of the scientific information regarding its use for therapeutic

purposes is related to its application through the iontophoresis procedure, that is, the transfer of drugs or medications loaded transcutaneously based on the physical principle of electro-repulsion of electric charges which facilitates the transport of the drug[3-8]. Works in the neurological area document transcranial applications to induce changes in the resting potential of neurons as a treatment for motor disorders, cognitive and behavioral in patients with brain damage, although these applications are more complex[9,10].

Within the physiological effects of DC, those that occur in the biological tissues underlying each electrode are described, those that have been called polar effects (PE), and that occur due to the accumulation of electric charges in the areas near each electrode as a consequence of the physical principle of electrophoresis[2,11,12]. Within the framework of EP, those activators or suppressors of motor nervous activity can be highlighted. The activating effects of the nervous system occur under the cathode (Cathode effects), and would be given by the facilitation of membrane depolarization of the excitable membranes (axolemma, neurilemma sarcolemma), as well as an inhibition of the activity of the acetylcholinesterase enzyme (AChE) at the level of the motor plate. On the other hand, inhibitory effects would occur under the anode (Anodic effects), and would consist of hyperpolarization of the excitable membranes and activation of the AChE at the level of the motor plate[2]. The polar effects would occur to a depth of 4 to 5cm, what would be sustained in the decrease of the impedance of the skin generated by the DC, and that it would be dependent on the application time (min) and the current density under the electrode (mA/cm^2)[13-15]. Based on this idea, neuromuscular activation or inhibition could be generated by changes in excitability of the motor plate. Variations in excitability could be reflected in increases or decreases in muscle strength.

Dynamometry is a way of quantifying muscle strength in specific body positions and for different joints. The types include manual dynamometry (grip dynamometry), whose objective is to measure the maximum static strength of the flexor muscles of the wrist and fingers when they are compressed[16]. The manual dynamometry has the advantage of being a simple test, easy to perform and with portable equipment, besides it is economically low-priced.

It is therefore interesting to assess the polar effects that facilitate and inhibit the activity of the nervous system, and changes in muscle strength.

The general objective of this study is to evaluate the polar effects, anode and cathode, on the manual grip strength in healthy subjects. The manual grip strength will be evaluated by dynamometry, recording the values of maximum strength in kilograms (kg), which will be considered as the primary study variable. A session of intervention will be carried out for convenience, to evaluate if with this minimum occur variation in the strength.

METHODOLOGY

Plan

The present plan represents a double blind randomized clinical trial (participants and applicators of the procedure). The research was approved on October 20, 2015 by the bioethics committee of the East Metropolitan Health Service (SSMO) with residence in the Hospital Salvador, Santiago city of Chile and later registered in www.clinicaltrials.gov (Protocol Registration and Result System) obtaining the registration ID NCT02884427. The maximum strength changes of manual grasping of the dominant upper limb before and after the application of DC on the motor point of the flexor muscles of the wrist and fingers were evaluated. The sample was divided into 3 working groups, applying in one group the effects of the Cathode and in another the effects of the Anode to be compared with a third group that will be a Control.

Subjects

One hundred and fifty healthy volunteer subjects (77 men, 73 women, age category between 18 and 40 years) were recruited. The participants were students of the School of Rehabilitation of the Andrés Bello University, Campus Casona, Santiago del Chile city. The number of participants was selected for convenience, taken from a total available population of 1150 people. The selection was made based on a survey whose first part was structured in relation to the general demographic data of the participants: name, age, gender, body mass index (BMI), career year, and personal contact information (email and cell phone). The data collected were considered as secondary variables. These data were tabulated with the software Microsoft Excel® 2013 and a table was constructed with them (Table 1).

Secondary variables, gender and age category were represented as frequencies (%). The variables maximum Strength of pre-intervention grasp (kg), weight, size and BMI were represented as averages with their standard deviation (x +/-DS). These data were analyzed with the STATAv.14 program, obtaining a p-value that statistically confirmed the homogeneity of the groups.

Table 1. Description of the variables measured by group operated before the intervention with DC

VARIABLE	GROUP 1 (CATHODE)	GROUP 2 (ANODE)	GROUP 3 (CONTROL)	p value
Gender. Frequencies (%)				
Male	21 (27,3)	30 (39,0)	26 (33,8)	0,376
Female	27 (37,0)	22 (30,1)	24 (32,9)	
Age category. Frequencies (%)				
< 20 years old	7 (29,2)	6 (25,0)	11 (45,8)	
20-29 years old	39 (33,3)	43 (36,8)	35 (29,9)	0,548
> 30 years old	2 (22,2)	3 (33,3)	4 (44,4)	
Weight. Average +/- DS				
Male	74,8 +/- 9,7	73,8 +/- 9,0	78,3 +/- 13,4	
Female	60,7 +/- 6,9	62,9 +/- 9,4	60,4 +/- 7,3	0,075
Total	66,9 +/- 10,8	69,2 +/- 10,6	69,7 +/- 14,1	
BMI. Average +/- DS				
Male	24,5 +/- 3,6	24,8 +/- 2,7	26,0 +/- 6,5	
Female	23,0 +/- 2,2	23,6 +/- 4,1	23,2 +/- 2,9	0,428
Total	23,6 +/3,0	24,3 +/- 3,4	24,7 +/- 5,3	
Maximum strength pre KG (Average +/- DS)				
Male	44,7 +/- 10,6	39,1+/- 8,1	39,9 +/- 9,3	0,08
Female	28,1 +/- 6,3	25,9 +/- 5,2	29,5 +/-11,0	0,259
Total (med, RIC)	34 (24-44)	28,5 (23 – 29)	29,5 (21-44)	0,1917

General description of the variables of the study subjects. No statistically significant difference was found between the groups. * frec (%) = frequency (percentage); ** DS= Standard deviation; med=median; RIC: Interquartile range. Group 1 corresponds to the group of patients who performed the intervention with DC applying the cathode in the target area. Group 2 corresponds to the group of patients who performed the intervention with a galvanic current using the anode in the target area. Group 3 corresponds to a control in which the intervention with current was not carried out. The p-value of the gender variable, age category was performed using the chi square statistical test (x^2). The p-value of the variable weight, BMI and pre-intervention muscle strength in the male and female gender was obtained by the one-way ANOVA test. The p-value of the muscle variable pre-total intervention was obtained by the K-WALLIS test.

The second part of the survey consisted of closed questions made in relation to the inclusion and exclusion criteria proposed by the study. The inclusion criteria included the participation of subjects over 18 years of age and without pain or discomfort when performing manual grasping. The subjects were excluded in case of having musculoskeletal pathologies of the hand, wrist or elbow in the last 6 months, presence of osteosynthesis materials or prosthesis in the upper limb, peripheral neurological pathologies, skin lesions or wounds in the forearm that would make the application of current in that region, apprehension or fear of electrotherapy.

Equipment

The electric stimulator COMBI 500 de GYMNA® (www.gymna.com) was used. The DC was applied for 12 minutes with maximum intensity of 2mA (dose 24mA.min) with electrodes of rubber of carbon of 48cm^2 area. The electrodes were coated with wet pads of 51cm^2, obtaining a current density of 0,0392mA/cm^2.

Measurement tools

A JAMAR hydraulic dynamometer was used and its measuring range is between 0 and 90kg (0 and 200lb)[16-18]. The maximum grip strength in kilograms (kg) exercised by the participants was evaluated when performing the manual grasping before and after the DC intervention, assessing the changes between both measurements.

Process

Selection of participant

The selection began with the delivery of a participation survey to students of different levels of the careers of the University. With the survey, general data of the students were obtained in order to generate the first filter of the subjects to determine the possible participants for the investigation. The analysis of the surveys was done in 3 days, obtaining a total of 153 potential participants. Then a personal contact was made with each of them to invite them to participate. 150 subjects agreed (77 men, 73 women). Each subject gave a written consent by signing the consent document approved by the bioethics committee of the East Metropolitan Health Service (SSMO), located in the Salvador Hospital, district Providencia (www.cec-ssmoriente-adultos.cl). After the signature the participant was labeled with a number to perform the randomization process. The participants were individually mentioned within the following 7 working days to the Electrotherapy laboratory of the FCR, room 401, building C5.

Division of the working groups

The sample was divided by a simple randomization process carried out with the software Microsoft Excel® 2013 obtaining three working groups. The randomization was in charge of the study director. The

working groups were designated as the Cathode group (Group 1, n=48), the Anode group (Group 2, n=52) and the Control group (Group 3, n=50) (Table 1).

The sequence of randomization and participants of each group was only known by the principal investigator, who was in charge of the process. It was the role of the director to refer each participant to the assigned group. The participants were not aware about which polar effect would be applied. After randomization each participant had to go to the dynamometry station. For Table 1 p-value of the variable weight, BMI and muscular strength before the intervention in the male and female gender was obtained by the ANOVA test of one factor. The p-value of the variable gender and age category was made by the statistical of chi square test (x^2). The p-value total of the variable of muscle strength before the intervention was obtained by the test of K-WALLIS.

Registration of Pre grip Strength Intervention (FMpre)

The evaluations of strength and application of electrotherapy were carried out in the afternoons, on Monday, Wednesday or Friday, after the school day (after 5:00 p.m.). A therapist was in charge of recording the maximum palmar grasping strength for the manual dynamometry test. The evaluation station consisted of a chair placed next to a table in which was the hydraulic dynamometer JAMAR. Each participant was instructed to sit with the back supported and with the feet on the ground. The auditor then installed an orthosis in the dominant upper limb that secured a position of 90° of elbow flexion and a neutral pronosupination of the forearm. The participant had to hold the dynamometer with the dominant hand without supporting the forearm[19]. The measurement protocol included 3 attempts of grasp of 5 seconds with an interval of 15 seconds, which included a total time of measurement of 1 minute. The therapist recorded the 3 maximum manual grip strength values measured in kilograms (kg) and recording the highest of the three attempts by recording it on the Excel sheet. This value was recorded as the "Maximum Strength Pre" (FMpre). Once the measurement was finished, the participant was taken to the electrotherapy stations.

Intervention with DC

Each group was handled in independent boxes by a therapist who would administer a specific intervention. In the subjects of each group were fitted a direct current equipment, putting one electrode on the ventral side of the dominant forearm while the other electrode closed the circuit on the opposite forearm. The electrical conduction wires of the electrotherapy equipment of each station were masked so that the therapist was unaware of the polar effect he was applying. The masking of the cables was done by placing two opaque insulating tapes, preventing the recognition of colors (black or red) in the output cables. An insulating tape had the letter "A" or "B" labeled for each cable, so that the applicator did not know if the masked electrode was the Cathode (black) or anode (red). Only the director of the investigation knew the polarity represented by each letter on the power line. The therapists were instructed to install and always apply the same electrode on the dominant forearm. The electrotherapy equipment for the Control group was connected to a faulty cable that did not give current, so it was a false installation, a situation unknown to the administrator and participants of this group. All the groups received an intensity of subsensory stimulation so that no participant perceived the emission of current. For the Cathode and Anode groups, the therapeutic electrode was installed at the motor point of the forearm and was representative of the flexor muscle group of the wrist and fingers (midpoint of the midline of the forearm, 3cm under the bend of elbow flexion). This was done under the regulations proposed by the non-invasive muscle assessment group in surface electromyography (SENIAM Project)[20]. The black electrode was applied to the Cathode group on the ventral side of the forearm looking for the excitatory polar effect, while to the Anode group was applied the red electrode in the same region to corroborate a diminishing effect of the stimulus of motor activity. The electrode was installed in the control group of the same letter of the Cathode group, with the same procedure described. The circuit was closed at the same point on the contralateral forearm.

Records of the Strength of Prehension Post-Intervention (FMpost)

After completing the intervention with DC, each participant returned to the dynamometer measuring station. The physiotherapist of this station repeated the same protocol of assessment done before the application of current, recording again the best value of maximum strength of grip in kilograms (kg) of the three attempts made within the time of 1 minute. The highest value

of the 3 attempts was recorded as the "Maximum Post Strength" (FMpost) and recorded on an Excel sheet.

RESULTS

Table 2 shows the results obtained by comparing the variables FMpre (Kg), FMpost (Kg) and "Maximum Strength Difference" (FMdif, Kg) broken down for men, women and the total number of participants for each of the working groups. The p-value of the FMpost variable in men was performed using the statistical one-way ANOVA test. The p-value of the variable FMpost in women was made by the K-WALLIS test. The p-value of the variable FMTpost was made by the K-WALLIS test. According to the results, statistically significant differences were not found between the groups in relation to the maximum strength difference before and after the application of electrotherapy. No significant differences were found between the groups in the variable FMpost in men, FMpost in women, or variable Maximum Strength post (FMpost) between the groups.

Table 2. General description of the variable Maximum strength pre (FMpre), Maximum Strength post (FMpost) and Maximum strength difference (FMdif) of the study groups

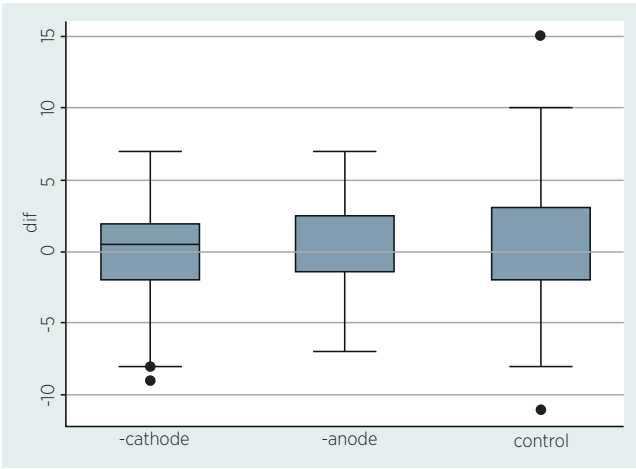
VARIABLE	GROUP 1 (CATHODE)	GROUP 2 (ANODE)	GROUP 3 (CONTROL)	p value
FMpre				
Male (Average +/-DS)	44,7 +/-10,6	39,1 +/- 8,1	39,9 +/-9,3	0,8
Female (Average +/-DS)	28,1 +/- 6,3	25,9 +/-5,2	29,5 +/-11,0	0,259
Total (med, RIC)	34 (24 – 44)	28,5 (23 – 29)	29,5 (21 – 44)	0,1917
FMpost				
Male (Average +/-DS)	44,2 +/- 10,4	40,2 +/- 9,2	41 +/- 11,3	0,3325
Female (med, RIC)	27 (23 – 20)	26 (22 – 29)	26 (20,5 – 33)	0,7506
Total (med, RIC)	33 (28 – 48)	30,5 (24 – 10)	32,5 (26 – 46)	0,9462
FMdif				
Male (med, RIC)	1 (-3 – 4)	0 (0 – 2)	0,5 (-2 – 2)	0,9462
Female (Average +/-DS)	-0,3 +/- 4,5	-0,8 +/- 4,1	-0,8 +/- 4,2	0,9189
Total (med, RIC)	0,3 +/- 4,7	0 +/- 4	-0,2 +/- 4,8	0,881

The p-value of the FMpost variable in men was performed using the one-way ANOVA statistical test. The p-value of the FMpost variable in women was made by the K-WALLIS test. The p-value of the variable FMTpost was made by the K-WALLIS test. There are no statistically significant differences between the groups in relation to the maximum strength difference before and after the application of electrotherapy. For the variable FMdif of males, test K-Wallis was used, while for women, FMdif and the total of the groups the ANOVA test was used with 1 factor. In the FMdif variable in men there is a slight increase, although statistically insignificant, in Maximum Streght in Group 1 (Cathode). In women there is a decrease in FMdif in group 2 (Anode), although this difference in maximum Strength (FMdif) is not statistically significant in this group.

The p-value of the FMdif variable in men was performed using the statistical test of K-WALLIS. The p-value of the FMdif variable in women was determined by the statistical test of one-way ANOVA. There is a slight tendency to increase of the FMdif for group 1 (Cathode) (0,3 +/- 4,7), while group 2 (Anode) remained unchanged (0 +/- 4) and the Control group showed a downward trend (-0,2 +/- 4,8).In relation to Graph 1, for group 1 (cathode) the values of Q1 and Q3 correspond to -2Kg and 2Kg respectively, with the median of 1Kg. For group 2 (anode) values of Q1 and Q3 of -1Kg and 2.5Kg, obtaining a value for the median of 0Kg. The Control group shows values of -2kg for Q1 and 3Kg for Q3, with median of 0kg in relation to the value. Considering the values of Q2, a slight tendency of positive variation of strength is observed for group 1 (cathode), while variations are not exhibited considering the same value. (*) It represents the atypical FMdif value for the observed data, where in group 1 (cathode) a value of -9Kg is observed, and -11Kg and 15Kg for the Control group.

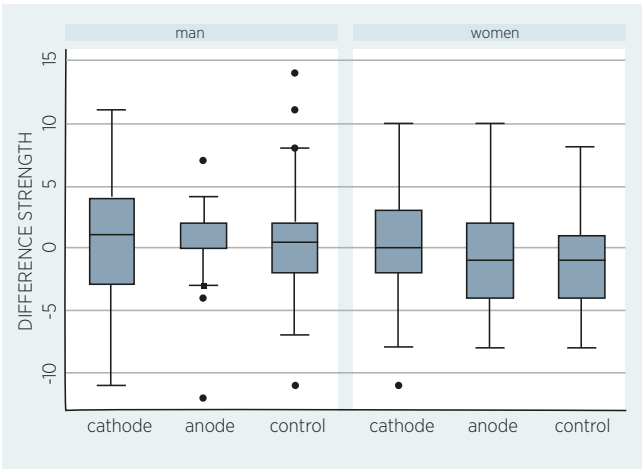
In Graph 2, for group 2 (anode) of males, there are two values of -4Kg, and of -13Kg in the negative area and of 7Kg for the positive area. For the male control group, atypical FMdif values of -11Kg and 14Kg are appreciated. (*).For the Cathode group of women, the values of Q1 and Q3 correspond to -2Kg and 3Kg respectively, with median of 0Kg. For group 2 (anode) of women values of Q1 and Q3 of -4Kg and 2Kg are obtained, with median value of -1Kg. Group 3 (control) of women shows values of -4Kg for Q1 and 1Kg for Q3, with median of -1Kg in relation to the value.

Considering the values of Q2, a possible decrease effect in FMdif is found in women in group 2 (anode), which could support the hypothesis of the inhibitory effect of the positive electrode compared to the cathode.



Graph 1. Chart of boxes that represent the values of differences of Maximum Strengh (FMdif) measured in kilograms (Y axis) for the three study groups arranged (X axis)

The 0 point of the Y axis represents the reference value to determine from this the positive and negative variation of FMdif in kilograms (Kg) for the three groups. The graph shows the values of Q1, Q2 and Q3 for the values observed in the three groups. For the group Cathode the values of Q1 and Q3 correspond to -2Kg and 2Kg respectively, with median of 1Kg. For the Anode group, values of Q1 and Q3 of -1Kg and 2,5Kg are appreciated, obtaining a value for the median of 0Kg. The Control group shows values of -2kg for Q1 and 3Kg for Q3, median of 0kg in relation to the value. Considering the values of Q2, a slight tendency of positive variation of the strength is observed for the Cathode group, while no variations are exhibited considering the same value. (*) Representation of the atypical FMdif value for the observed data, in the Cathode group a value of -9Kg is observed, and -11Kg and 15Kg for the Control group.



Graph 2. Graph of boxes that represent the values of differences of Maximum Stregth (FMdif) measured in kilograms (Y axis) for the 3 study groups arranged (X axis) but considering the sex

The 0 point of the Y axis represents the reference value to determine from this the variations of positive and negative FMdif in kilograms (Kg) for men and women of the 3 groups. The graph expresses the values of Q1, Q2 and Q3 for the values observed in the three groups according to the sex of the participants. (*) Representation of the atypical FMdif value for the observed data of males, the values of Q1 and Q3 correspond to -3Kg and 4Kg respectively, with median of 1Kg. For the Anode group of males, values of Q1 and Q3 of 0kg and 2kg are appreciated, obtaining a median of 0Kg. The group Control of males shows values of -2Kg for Q1 and 4Kg for Q3, the median of 1Kg in relation to the value. Considering the Q2 values of the 3 groups, a slight tendency to increase the FMdif value was observed in men in the Cathode and Control group, while in the Anode group there were no variations. (*) Representation of the atypical FMdif value for the observed data, in the group Anode of males, two values of -4Kg are observed, and of -13Kg in the negative area.

When comparing the FMDIF changes obtained only by men, a minimum increase of grip strength is found in group 1 (Cathode), although not statistically significant, which could support the hypothesis of our work that DC through the cathodic effect would favor neuromuscular activation, although again the differences are not statistically significant. On the other hand, the comparison of the women of the three groups indicates a decrease of the FMdif for the three working groups, but not with statistical significance too. In group 2 (anode) there was a greater decrease (-0,8 + / 4,1) compared to the cathode group (-03 +/- 4,5). In a comparison between women, the hypothesis that the polar effect of the cathode using DC would be activating would be rejected, however, if an inhibiting effect could be presumed by the anode.

DISCUSSION

The theory states that direct current through its polar effects (cathode and anode) would facilitate or inhibit neuromuscular activity at the level of the motor plate, however, there is little documentation about this topic. In the framework of this experimental design, we tried to assess the effects of neuromuscular stimulation through the polar effects of DC. When analyzing the data of the total strength difference before and after the application of the current in the different groups, no significant changes are observed in a comparison. Despite this with the variable gender, there is a minimum increase in FMdif in men after the application of the current using the cathode. A possible explanation for this fact could be that men have more trained brachial and antebrachial musculature, because in their normal activities of daily life tend to perform more strength[19-21]. This could be associated with the fact that in the face of an electrical stimulation they would react in a better way than women due to motor thresholds of lower muscular activation, thus increasing their strength. Another possible explanation of the trends to the increase could be due to the amount of fat tissue, with the men having a lower proportion than the women, which favors that the current can penetrate easier by having less resistance[22,23]. This non-significant difference of increasing in FMdif using the cathode is interesting, as it can be used in other future investigations, perhaps improving the protocol, to support the theory that this type of current can affect neuromuscular activation. The protocol improvement includes using higher currents,

longer application times, variation of rest times in FMpre and FMpost measurements, or more work sessions to track long-term changes. On the other hand, women show a decrease in neuromuscular activation for the three groups, concentrating the decrease of FMdif in the anode and control groups. The explanation could also be related to the activation motor threshold, which may be higher in women or the percentage of body fat[24-26]. When reflecting, it is true that women are generally not as strong as men and women's body constitution is biologically constructed for different purposes. Due to different sizes and functions, the same muscle groups and the potential to gain strength work in different scales[27,28].

This design has some limitations that are specific to scientific work. One of the limitations is related to the size of the sample, which is still an interesting number but it is not clear if it is sufficient because the calculation was not applied for its determination and the work was done for convenience.

The first reflection focuses on the dose and number of intervention sessions. In this work the dose was adjusted according to what is documented by the available literature[2,5]. It may be possible that with more intensity or time (mA.min) clearer effects could be achieved, according to the Arnoldt Schultz principle, in which the physiological effect achieved is proportional to the magnitude of the applied stimulus[1,2]. Also, a greater number of sessions could generate potentiation of the physiological effect sought. In the work we sought to evaluate if a session could have been sufficient. Another aspect is related to the depth of this current, subject to the impedance of the biological tissues[2,5,6,8], although that was the reason that led to the work on the forearm to have a lower skin thickness and less fat tissue compared with other areas, to ensure the effect at the muscular level. Another aspect to consider is that the participants could have been self-convinced to increase the strength after the application of the current, this may influence them in the moment of conducting the test negatively influencing the values thrown. Another limitation of the study is the age range of the participants, which is more centralized in students, it could be that there are variations in other age groups[28]. Another limitation may be that the participant was unaware of the practical way of doing the test of grip with dynamometry, and the time of familiarization with the instrument may have been insufficient, providing a session to learn the procedure of dynamometry.

CONCLUSION

The results demonstrate that the DC application used in this study shows there were no variations in muscle strength using the polar effects of the cathode and anode. Although there is an increase in grip strength in men when using the cathode, and a decrease in grip strength in women with the anode, there is no statistical significance to support these variations. It would be interesting to develop more research regarding the use of DC for the purposes of neuromuscular facilitation, using models with another dosage and a greater number of interventions over time. This is the first work that tries to assess changes in neuromuscular activation when working with DC. It is proposed to continue with research in this area, giving value to the results of the FMdif obtained for men and women by using the effects of the cathode and anode respectively.

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REFERENCES

1. Cameron MH, organizadora. Physical agents in rehabilitation: from research to practice. 4th ed. Amsterdam: Elsevier; 2013. Part IV, Electrical currents; p. 223-39.
2. Martin JMR. Electroterapia en fisioterapia. 3ª ed. Madrid: Editorial Médica Panamericana; 2013. Capítulo VI, Aplicaciones y tratamiento con galvanismo; p. 181-204.
3. Kalia YN, Naik A, Garrison J, Guy RH. Iontophoretic drug delivery. Adv Drug Deliv Rev. 2004;56(5):619-58. doi: 10.1016/j.addr.2003.10.026
4. Kahn J. Iontophoresis. Phys Ther. 1984:64(6):956-9.
5. Conjeevaram R, Banga AK, Zhang L. Electrically modulated transdermal delivery of fentayl. Pharm Res. 2002;19(4):440-4. doi: 10.1023/A:1015135426838
6. Guy RH, Delgado-Charro MB, Kalia YN. Iontophoretic transport across the skin. Skin Pharmacol Appl Skin Physiol. 2001;14 Supl 1:35-40. doi: 10.1159/000056388
7. Hamann H, Hodges M, Evans B. Effectiveness of iontophoresis of antiinflammatory medications in the

treatment of common musculoskeletal inflammatory conditions: a systematic review. Phys Ther. 2006;11(3):190-4. doi: 10.1179/108331906x144082

8. Li CL, Scudds RA, Heck CS, Harth M. The efficacy of dexamethasone iontophoresis for the treatment of rheumatoid arthritic knees: a pilot study. Arthritis Care Res. 1996;9(2):126-32.
9. Donaldson PH., Kirkovski M, Rinehart NJ, Enticott PG. Autism-relevant traits interact with temporoparietal junction stimulation effects on social cognition: a high-definition transcranial direct current stimulation and electroencephalography study. Eur J Neurosci. 2017 set. 27:[13 p.]. doi: 10.1111/ejn.13675
10. Fan J, Li Y, Yang Y, Qu Y, Li S. Efficacy of noninvasive brain stimulation on unilateral neglect after stroke: a systematic review and meta-analysis. Am J Phys Med Rehabil. 2017 set. 25. doi: 10.1097/phm.0000000000000834
11. Morillo MM, Vega JMP, Portero FS. Manual de medicina física. San Diego: Harcourt Brace; 1998. p. 68-150.
12. Plaja J. Guía práctica de electroterapia. Barcelona: Electromedicarin; 1998. p. 9-27.
13. Fujita M, Hukuda S, Doida Y. The effect of constant direct electrical current on intrinsic healing in the flexor tendon in vitro. An ultraestructural study of differing attitudes in epitenon cells and tenocytos. J Hand Surg Eur Vol. 1992;17(1):94-8. doi: 10.1016/0266-7681(92)90021-s
14. Petelenz TJ, Buttke C, Bonds LB, Lloyd JE, Beck RL, Stephens SC. Iontophoresis o dexametasone: laboratory studies. J Control Release. 1992;20(1):55-66. doi: 10.1016/0168-3659(92)90139-i
15. Benjamin SJ, Flood JN, Bechtel R, Alon G. Measurement of soft tissue temperature and impedance following the appliation of transdermal direct currect. Physiotherapy. 2007;93(2):114-20. doi: 10.1016/j.physio.2006.11.008
16. O'Driscoll SW, Horii E, Ness R, Cahalan TD, Richards RR, An KN. The relationship between wrist position, grasp size, and grip strength. J Hand Surg Am. 1992;17(1):169-77. doi: 10.1016/0363-5023(92)90136-d
17. Innes E. Handgrip strength testing: a review of the literature. Aust Occup Ther J. 1999;46(3):120-40. doi: 10.1046/j.1440-1630.1999.00182.x
18. Bellace JV, Healy D, Besser MP, Byron T, Hohman L. Validity of the Dexter evaluation system's Jamar dynamometer attachment for assessment of hand grip strength in normal population. J Hand Ther. 2000:13(1):46-51. doi: 10.1016/S0894-1130(00)80052-6
19. Roberts HC, Denison HJ, Martin HJ, Patel HP, Sydall H, Cooper C, et al. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. Age Ageing. 2011;40(4):423-9. doi: 10.1093/ageing/afr051
20. Mathiowetz V, Weber K, Volland G, Kashman N. Reliability and validity of grip and pinch strength evaluations. J Hand Surg. 1984;9(2):222-6. doi: 10.1016/S0363-5023(84)80146-x
21. The European project Surface EMG for non-invasive assessment of muscles (SENIAM) [homepage na Internet]. [local desconhecido]: Seniam; [s.d.][citado em 2018 fev 7]. Disponível em: <https://goo.gl/DgZa41>.
22. Salmons SJ, Henriksson J. The adaptive response of skeletal muscle to increased use. Muscle Nerve. 1981;4(2):94-105. doi: 10.1002/mus.880040204
23. Bigland-Ritchie B, Woods JJ. Changes in muscle contractile properties and neural control during human muscular fatigue. Muscle Nerve. 1984;7(9):691-9. doi: 10.1002/mus.880070902
24. Currier DP, Mann R. Muscular strength development by electrical stimulation in healthy individuals. Phys Ther. 1983;63(6):915-21. doi: 10.1093/ptj/63.6.915
25. Mialich MS, Martinez EZ, Jordão Junior AA. Application of body mass index adjusted for fat mass (BMIfat) obtained by bioelectrical impedance in adults. Nutr Hosp. 2014;30(2):417-24. doi: 10.3305/nh.2014.30.2.7242
26. Popp KL, Hughes JM, Martinez-Betancourt A, Scott M, Turkington V, Caksa S, et al. Bone mass, microarchitecture and strength are influenced by race/ethnicity in young adult men and women. Bone. 2017;103:200-8. doi: 10.1016/j.bone.2017.07.014
27. Morimoto A, Suga T, Tottori N, Wachi M, Misaki J, Tsuchikane R, et al. Association between hand muscle thickness and whole-body skeletal muscle mass in healthy adults: a pilot study. J Phys Ther Sci. 2017;29(9):1644-8. doi: 10.1589/jpts.29.1644
28. Neumann S, Kwisda S, Krettek C, Gaulke R. Comparison of the grip strength using the Martin-Vigorimeter and the JAMAR-dynamometer: establishment of normal values. In Vivo. 2017;31(5):917-24.