Effects of ascending and descending direct current on grip strength assessed through dynamometry and myofeedback: a randomized controlled trial

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Abstract

Introduction. To investigate effects of ascending and descending direct current (ADC and DDC) on muscle strength evaluated with dynamometry. Muscle strength values in kilograms were compared in 3 groups (ADC, DDC, and control) before and after galvanic electrical intervention.

Methods. A randomized clinical trial was performed in the Physiotherapy Laboratory of Andrés Bello University among 83 healthy volunteers. The intervention was a direct current session at an intensity of 4 mA for 12 minutes with 48-cm^2 electrodes (dose: 48 mA · min; current density: 0.04 mA/cm^2). The difference between the groups was galvanic therapy type applied. Current application followed a hand dynamometric test and myofeedback evaluation. The main outcome was maximum strength difference (MSdif) and its corresponding value in microvolts (μV-MSdif) obtained with myofeedback.

Results. There were statistically significant changes regarding MSdif in groups who received direct current ($p = 0.0001$). These variations were also seen when comparing the 3 groups with the consideration of men ($p = 0.0012$) and women ($p = 0.0021$) separately. No statistically significant changes were observed in the μV-MSdif values ($p = 0.9409$).

Conclusions. ADC can generate variations in grip strength after an intervention session, with an increase in strength of 8.9%. The increase in strength was observed both in men (6.7%) and in women (9%) of the ADC group.

Key words: randomized controlled trial, hand strength, handheld dynamometry, electrical stimulation therapy, transcutaneous electric nerve stimulation

Introduction

Electrotherapy is currently used by physiotherapists with various therapeutic purposes, such as pain management, oedema resolution, tissue healing, and muscle training [1]. Although the literature describes a wide variety of electric currents [1], most clinicians apply transcutaneous electrical nerve stimulation or kilohertz frequency alternating current for analgesic or neuromuscular electrical stimulation in their daily practice [2–6]. Direct current (DC) or galvanic current is one of the oldest modalities in electrotherapy. It is characterized by being unidirectional, continuous, and by constant intensity. Unlike in other electric currents, DC parameters only involve intensity (mA) and treatment time (min). For this current, characteristic biological responses have described that are not obtained with other forms of currents; these are called polar effects. Polar effects result from accumulation of electrical charges under the electrodes and seem responsible for physiological responses such as tissue pH changes, local circulatory modifications, acetylcholinesterase activity alterations, or changes in neuronal excitability [7]. Polar therapeutic applications generally include transverse galvanic therapy, in which the target electrode is placed in the treatment area, with the other electrode closing the circuit contralaterally [7, 8]. It is estimated that the depth of the polar effects is up to 4 cm, given by the increase of skin impedance to unidirectional currents. Skin impedance would be dependent on treatment time (min) and current density (mA/cm^2) [9–11]. Literature suggests treatment times of 10–15 min for galvanic applications and current densities not greater than 0.2 mA/cm^2 for each electrode. These recommendations are based on potential adverse effects of DC, which can generate electrochemical burns (alkaline or acid), risk that is dependent on emission time and intensity [1, 12]. However, therapeutic times described would not apply when DC is used in iontophoresis, or transdermal drug delivery, where treatment times of 30 min or more can be reached [13–16].

In addition to polar effects, literature describes a sedative impact (galvanic narcosis) or excitatory activity of the nervous system in longitudinal galvanic therapy applications, that is, placing the electrodes longitudinally, following the nervous system distribution. These effects refer organism behaviour as a voltaic cell that can be charged or discharged [12]. Longitudinal galvanic applications have been called 'Leduc ascending and descending current effects'. Their main differences lie in the polarity of electrode that is located proximally, be it cathode or anode. Excitatory and hypertonic nervous system activity is suggested when the cathode is placed proximally and anode distally (ascending current), and hypotonic, sedative action with diminished reflexes can occur if the anode is located proximally and cathode distally (descending current). Inhibitory or excitatory effects would be given by the electrode arranged proximally, which owing to its polar nature would be a neural activity facilitator or inhibitor [1]. This foundation would be the basis to consider applications of longitudinal galvanic therapy and their corresponding variations of nervous excitability, as promoters or inhibitors of neuromuscular activity [1]. Information available regarding the ef-

fects of Leduc is scarce, with only a few studies that attempted to investigate changes in the motor excitatory threshold [12], in addition to some research describing transcranial applications to induce variations in the rest potential of neurons as an intervention in motor, cognitive, and behavioural disorders among patients with neurological conditions [17, 18]. Leduc effects could be useful as a therapeutic alternative in different clinical conditions that involve alterations in muscle tone, strength, or neural activity [1, 2]. Muscle activity or strength is a good indicator of efferent response of the nervous system and is used to assess nervous system function. Any major change in outgoing nerve conduction will be reflected as a variation of neuromuscular response [19–21].

A non-invasive procedure to evaluate muscle electrical activity is myofeedback, a surface electromyography system that monitors, through surface electrodes, the electrical potential differences of muscle fibres, quantified in microvolts (μV), when the muscles contract [1]. Myofeedback is used by some physiotherapists as an instrument for neuromuscular control activity evaluation and treatment, applied in musculoskeletal, neurological, and gynaecological areas [22–25]. One way to quantify muscle strength for different body segments is dynamometry. A type of dynamometry includes grip dynamometry, whose objective is to measure the maximum static force of the muscles involved in a grasp and, in some cases, to measure changes in vital parameters [26, 27]. Manual dynamometry has the advantage of being a simple test, easy to execute, portable, and inexpensive [28]. It is interesting to evaluate the excitatory and suppressive effects of the neuromuscular activity and any changes in the motor response generated by the Leduc effects.

In this way, the present paper seeks to resume DC investigations because its potential excitatory or inhibitory neuromuscular effects produced by the unique bioelectric properties could expand the therapeutic opportunities in interventions that seek to activate or depress nervous system activity.

The general objective of the research was to assess the effects of ascending DC (ADC) and descending DC (DDC) on grip strength in healthy subjects, being muscular strength the direct reflection of nervous system efferent activity. Grip strength was evaluated with the use of manual dynamometry, registering the maximum strength values (kg), considered as the primary variable of the investigation. Simultaneously, electrical potential difference (μV) was measured. The corresponding maximum strength value was assessed with myofeedback. The intervention session would be held for convenience.

Subjects and methods

Design

The design represents a randomized double-blind (participants and procedure applicators) clinical trial. The study was registered at www.clinicaltrials.gov under the number of ID NCT03150823. Maximum grip strength changes of the dominant upper limb were evaluated before and after DC longitudinal galvanic therapy. The sample was divided into 3 groups. ADC and DDC was applied in two of them, and both were compared with the control group.

Subjects

A total of 83 healthy volunteer subjects were recruited (42 men, 41 women; average age: 22 years). The participants were students of Andrés Bello University, Physical Therapy

career. An invitation to participate was distributed via the internal channels of the faculty (mailing), student centres, and social networks; 195 participants were obtained. Selection was based on a survey. Its first part was structured in relation to the general demographic data, that is name, age, sex, body mass index (BMI), career year, and personal information contact (e-mail and cell phone number). The second part of the survey consisted of closed questions involving the inclusion and exclusion criteria proposed. Subjects were included if they were older than 18 years and did not manifest pain or discomfort when performing grip with their dominant limb. Exclusion criteria were the following: musculoskeletal conditions as tendinopathies, sprains, fractures, or muscle injuries in hand, wrist, or elbow within the previous 6 months, presence of osteosynthesis materials or prostheses in the dominant upper limb, peripheral neurological pathologies, skin lesions or wounds of forearm that would affect the application of current in that region, apprehension or electrotherapy fear. An elimination criterion was also not having completed the evaluation and treatment protocol. The participants' demographic data were elaborated in Microsoft Excel® 2013 software (Table 1).

Secondary variables such as age and BMI were presented as medians, while sex and nutritional status were presented as frequencies (%). The variables of pre-intervention maximum strength grasp (preMS) and pre-intervention electrical potential value of maximum strength grasp (μV-preMS) were expressed as medians with their corresponding interquartile ranges (IQR). The data were later analysed with the STATA v.13 software, which confirmed the statistical homogeneity of the groups.

Equipment

A Combi 500 electric stimulator from Gymna® was used. DC was applied for 12 min at a maximum intensity of 4 mA (dose: 48 mA · min) with the use of 48-cm^2 area electrodes. The electrodes were coated with wet pads of 51 cm^2, which resulted in the current density of 0.0784 mA/cm^2.

Measurement tools

A Jamar® hydraulic dynamometer was used for maximum grip strength assessment. It provides a range of 0–90 kg of measurement [29–31]. Maximum strength difference (MSdif) (kg) exerted by the subjects was obtained by changes between maximum grip strength before and after DC intervention.

Electrical potential difference was evaluated with the biofeedback equipment MYO 200®. Adhesive 25-cm^2 electrodes were placed in the anterior dominant forearm region, registering the corresponding values (μV) of muscle involved for each maximum grip while performing the dynamometry test.

Procedure

Participants

Selection was made by means of a written survey that allowed identifying potential participants. Overall, 195 surveys were analysed, which resulted in obtaining 87 potential participants. A total of 83 agreed to participate (42 men, 41 women). The researchers assigned a number to each participant to generate the randomization process. The subjects were individually evaluated in the following 20 days in the Physiotherapy Laboratory of Andrés Bello University.

Table 1. Characteristics of the study groups

Variable	ADC group (n = 28)	DDC group (n = 24)	Control group (n = 31)	Total (n = 83)	p	Sample distribution
Age, median (IQR)	22 (21–23)	21.5 (20.5–22)	22 (20–23)	22 (21–23)	0.5101*	Non-normal
Sex, frequency (%)						
Men	12 (13.3)	16 (18.1)	17 (19.3)	43 (50.6)	0.2460*	Normal
Women	18 (20.5)	10 (11.0)	16 (18.1)	42 (49.4)		
BMI, median (IQR)	23.0 (22.0–25.7)	23.8 (22.6–25.7)	24.4 (22.6–27.4)	24.3 (22.6–26.4)	0.6120*	Non-normal
Nutritional status, frequency (%)						
Underweight	1 (1.2)	0 (0.0)	0 (0.0)	1 (1.2)	0.4750*	Normal
Normal	16 (19.3)	16 (19.3)	19 (22.9)	51 (61.5)		
Overweight	10 (12.1)	6 (7.2)	12 (14.5)	28 (33.7)		
Obese	1 (1.2)	2 (2.4)	0 (0.0)	3 (3.6)		
preMS (kg), median (IQR)	22.5 (20–28.5)	28 (20–36.5)	32 (22–35)	28 (25–20)	0.2293*	Non-normal
µV-preMS (µV), median (IQR)	375.5 (301–516.5)	300 (249–380)	376 (246–528)	355 (252–496)	0.1354*	Non-normal

Data with non-normal distribution were analysed with the non-parametric Kruskal-Wallis test. Data with normal distribution were analysed with the chi-squared test.
ADC – ascending direct current, DDC – descending direct current, IQR – interquartile range, BMI – body mass index, preMS – pre-intervention maximum strength grasp, µV-preMS – pre-intervention electrical potential value of maximum strength grasp
* $p > 0.05$

Groups

The sample was divided, by a simple randomization process performed with a random number table, into 3 groups. The sequence of randomization and participants of each group was only known by the principal investigator, who oversaw the process. The groups were labelled as the ADC group (n = 28), the DDC group (n = 24), and the control (n = 31). None of the subjects was aware of the DC modality assigned. Each participant was led by the principal investigator to the dynamometry box. The p values presented in Table 1 for the variables of age, BMI, preMS, and electric potential difference associated with the preMS were obtained with the Kruskal-Wallis test. The p values for the variables of sex and nutritional status were established with the chi-squared test.

Pre-intervention maximum strength (preMS) and pre-intervention electrical potential difference evaluation (µV-preMS)

Strength assessments and electrotherapy application were performed in the mornings on Tuesdays and Thursdays for 2 months. A physiotherapist oversaw registering the maximum strength for the manual dynamometry test.

An evaluation station consisted of a chair and a table with the Jamar® hydraulic dynamometer. Subjects sat with their back supported with both feet on the floor.

The evaluator installed the electrodes of the biofeedback equipment on the anterior face of the dominant forearm and placed the reference electrode (ground) on the ipsilateral biceps brachii muscle. The electrodes were placed 3 cm from the midpoint of the elbow flexion fold, following the axis from this point to the middle finger, keeping 2 cm between them. The reference electrode was installed at the midpoint of ipsilateral biceps brachii muscle, following a line between the anterior portion of the acromion and the midpoint of the elbow flexion fold. This would allow to record the changes (µV) for each manual grasping attempt. Each participant had to hold the dynamometer with the dominant hand, without sup-porting the forearm, maintaining 90° of elbow flexion and a neutral pronosupination [32, 33]. The measurement protocol included 3 grasp attempts for a maximum voluntary contraction in a time of 3 s, with an interval of 60 s [34]. The measurement was performed with the participant connected to the biofeedback equipment, which allowed for recording for each grip attempt. The evaluator registered 3 maximum grip strength values (kg) and their corresponding µV values. The best value and its corresponding recorded µV value with myofeedback were considered preMS and µV-preMS. Once the measurement was finished, the participant was taken to the electrotherapy stations.

Direct current intervention

The intervention was carried out in the Physiotherapy Laboratory of Andrés Bello University. The laboratory had 3 boxes to enable interventions with the participants of each group independently (ADC group, DDC group, control group). The interventions were performed by 3 therapists with knowledge of electrotherapy and with more than 3 years of experience in the musculoskeletal area. A peripheral longitudinal galvanic therapy was installed to each participant [13]. Before the application, the subjects had to wash their hands. The installation included placement of an electrode in the proximal third of the anterior surface of the dominant forearm, immediately under the elbow fold flexion, and another one in a plastic bucket (capacity: 12.5 l) with water at 25°C, in order to perform the immersion of the same side hand to close the circuit. Water covered the participant's hand and wrist.

Output cables of the electrotherapy equipment channels for each station were masked and labelled A and B, so that the therapist had no knowledge of the Leduc effect that was being applied. Output cable A represented cathode, while B represented anode. Masking was done through opaque strips, preventing the recognition of the colours (black or red) for the output cables. Only the principal investigator knew the polarity o each cable. Each therapist was instructed

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to install an electrode on the dominant forearm and the other one in the bucket. The difference was that A or B were placed proximally, depending on the group. Electrotherapy equipment for the control group was connected to a faulty cable that did not provide electrical power, so it was a simulated installation, a situation unknown for therapy administrator and group participants. All groups received a stimulation intensity of 4 mA for 12 min (dose: 48 mA · min). It was explained to the participants that they might not feel the current emission, as it depended on the individual biological characteristics, for example, percentage of body fat, which could vary the impedance of the tissues to the passage of electric current [12]. For the ADC group (excitatory effect), electrode A was installed on the forearm and electrode B on the bucket, while for the DDC group (inhibiting effect) the position was inverted. In the control group, the ADC group installation was imitated, but without current emission. For electrotherapy application, 2 carbon rubber electrodes were used (surface area: 48 cm^2). The electrodes were covered with wet pads of 51 cm^2.

Post-intervention maximum strength (postMS)
and post-intervention electrical potential difference
evaluation (µV-postMS)

On completing DC intervention, each participant returned to the dynamometer station. The evaluator repeated the assessment protocol applied before the current application, recording again the best value of maximum grasp strength (kg) after performing the 3 attempts. Simultaneously, electrical potential difference (µV) was recorded with myofeedback for each attempt. Highest attempt value was recorded as the post-intervention maximum strength (postMS) and the corresponding *µV* values were recorded as post-intervention electrical potential difference of maximum strength (*µV-postMS*).

Ethical approval
The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and was approved on June 24, 2018 by the bioethics committee of the Metropolitan Eastern Health Service of the Metropolitan Region.

Informed consent
Informed consent has been obtained from all individuals included in this study.

Results

The sample was categorized in relation to age, sex, BMI, nutritional status, preMS, and its corresponding µV-preMS value, and the Shapiro-Wilk test was applied to analyse distribution (Table 1). For age, median was calculated and equalled 22 years (IQR: 21–13) in the ADC group, 21.5 years (IQR: 20.5–22) in the DDC group, and 22 years (IQR: 20–23) in the control group; statistical analysis was performed with the Kruskal-Wallis test, which revealed no significant difference between the groups (*p* = 0.5101). Sex was obtained for a sample of 28 participants in the ADC group (11 men, 17 women), for 24 subjects in the DDC group (15 men, 9 women), and for 31 participants in the control group (16 men, 15 women). Statistical analysis for sex was performed with the use of the chi-squared test, which did not show a significant difference between the groups (*p* = 0.246). For BMI, medians were determined and equalled 23.0 (IQR: 22.0–25.7) for the ADC group, 23.8 (IQR: 22.6–25.7) for the DDC group, and

24.4 (IQR: 22.6–27.4) for the control group. BMI was analysed by the Kruskal-Wallis test, without any statistical difference (*p* = 0.612). When comparing the nutritional status of the 3 groups, we obtained only 1 underweight participant, 16 normal weight, 10 overweight, and 1 obese in the ADC group; in the DDC group, 16 subjects were normal weight, 6 overweight, and 2 obese; in the control group, 19 participants were normal weight and 12 overweight. Statistical analysis for this variable was performed with the chi-squared test, which did not present significant differences (*p* = 0.475). For preMS, medians were calculated and equalled 22.5 kg (IQR: 20–28.5) for the ADC group, 28 kg (IQR: 20–36.5) for the DDC group, and 32 kg for the control group. The analysis was carried out with with the Kruskal-Wallis test; no statistically significant differences were found. For µV-preMS, medians were determined and equalled 375.5 µV (IQR: 301–516.5) for the ADC group, 300 µV (IQR: 249–380) for the DDC group, and 376 µV (IQR: 246–528). for the control group. When performing the statistical test of Kruskal-Wallis, no statistically significant differences were found between the groups (*p* = 0.9409).

The statistical analysis performed in relation to the variables of age, sex, BMI, preMS, and the corresponding µV-preMS values before the application of electrotherapy, observed in Table 1, did not reveal statistically significant differences, so the groups are comparable.

Table 2 shows the results obtained for the variables of preMS (kg), postMS (kg), and MSdif (kg) represented for men, women, and all participants for each group. The results for MSdif and the respective µV-MSdif were compared; a difference was observed between postMS and preMS, and µV-postMS and µV-preMS. The Shapiro-Wilk test was applied to analyse the distribution of these variables.

For postMS (kg), medians were estimated and equalled 26.5 (IQR: 23–30) in the ADC group, 27.5 (IQR: 19.5–33.5) in the DDC group, and 30 (IQR: 20–34) in the control group. The statistical analysis was performed with the Kruskal-Wallis test, with no significant differences between the groups (*p* = 0.8500). For MSdif (kg), medians were obtained and equalled 2 (IQR: 1–3) in the ADC group, –1 (IQR: from –4.5 to 1) in the DDC group, and –2 (IQR: from –4 to 0) in the control group. The statistical analysis was performed with the Kuskal-Wallis test and statistically significant differences were obtained (*p* = 0.0001), which indicates changes of strength between groups. This variation was expressed mainly in the ADC group, increasing its strength statistically.

For µV-MSpost (µV), medians were estimated and equalled 381.5 (IQR: 318.5–517) for the ADC group, 338 (IQR: 227–383) for the DDC group, and 366 µV (IQR: 276–422) for the control group. Statistical analysis was performed with the Kruskal-Wallis test, without significant differences between the groups (*p* = 0.1372). For µV-MSdif (µV), medians were obtained and equalled 16 (IQR: from –26.5 to 44.5) in the ADC group; –10 (IQR: from –40 to 39.5) in the DDC group, and 0 (IQR: from –72 to 66) in the control group. The Kruskal-Wallis test was applied rather than statistically significant differences found between groups (*p* = 0.9409).

Figure 1 shows MSdif registered between groups, expressed in general and by sex. The statistical analysis was carried out with the Kruskal-Wallis test, in which a statistically significant difference was obtained between groups and by sex. A post-estimation analysis was performed with Dunn's pairwise comparison test; a significant difference was found for groups when comparing MSdif between the ADC and DDC groups (*p* = 0.0000). There were greater differences in the ADC group and also when comparing the ADC group with

Table 2. Hand grip strength and respective µV values pre-intervention, post-intervention, and their differences

Variable, median (IQR)	ADC group (n = 28) Men (n = 11) Women (n = 17)	DDC group (n = 24) Men (n = 15) Women (n = 9)	Control group (n = 31) Men (n = 16) Women (n = 15)	Total (n = 83) Men (n = 42) Women (n = 41)	p
preMS (kg)	22.5 (20–28.5)	28 (20–36.5)	32 (22–35)	28 (25–20)	0.2293
Men	30 (22–40)	35 (28–38)	35 (33–39.5)	34 (30–38)	0.2214
Women	22 (20–25)	19 (19–20)	22 (16–24)	21 (19–24)	0.1725
postMS (kg)	26.5 (23–30)	27.5 (19.5–33.5)	30 (20–34)	28 (22–33)	0.8500
Men	30 (27–42)	32 (27–37)	34 (32.5–35.5)	33 (30–36)	0.3505
Women	24 (22–26)	19 (16–21)	22 (15–24)	22 (17–25)	0.0485
MSdif (kg)	2 (1–3)	–1 (from –4.5 to 1)	–2 (from –4 to 0)	0 (from –2 to 2)	0.0001*
Men	2 (1–5)	–3 (from –7 to 1)	–2 (from –4 to 0)	–0.5 (from –4 to 2)	0.0012*
Women	2 (1–3)	0 (0–1)	–2 (from –3 to 1)	1 (from –1 to 2)	0.0021*
µV-preMS (µV)	375.5 (301–516.5)	300 (249–380)	376 (246–528)	355 (252–496)	0.1354
Men	379 (301–547)	340 (250–434)	399 (285–564)	373 (254–528)	0.3071
Women	370 (301–482)	282 (248–341)	344 (226–451)	344 (248–451)	0.2181
µV-postMS (µV)	381.5 (318.5–517)	338 (227–383)	366 (276–422)	361 (280–433)	0.1372
Men	381 (341–536)	337 (235–376)	406 (370–484)	375 (324–506)	0.0749
Women	382 (312–486)	374 (219–383)	294 (248–360)	340 (264–399)	0.2942
µV-MSdif (µV)	16 (form –26.5 to 44.5)	–10 (from –40 to 39.5)	0 (from –72 to 66)	0 (from –44 to 49)	0.9409
Men	–1 (from –37 to 49)	–19 (from –60 to 29)	–15 (from –81 to 98)	–16 (from –51 to 49)	0.8582
Women	16 (from –16 to 31)	–3 (from –29 to 42)	4 (from –72 to 62)	16 (from –29 to 43)	0.9606

Data analysed by using the non-parametric Kruskal-Wallis test* to compare intergroup differences and intergroup difference considering sex. IQR – interquartile range, ADC – ascending direct current, DDC – descending direct current, preMS – pre-intervention maximum strength grasp, postMS – post-intervention maximum strength grasp, MSdif – maximum strength difference, µV-preMS – pre-intervention electrical potential value of maximum strength grasp, µV-postMS – post-intervention electrical potential value of maximum strength grasp, µV-MSdif – electrical potential difference of maximum strength grasp
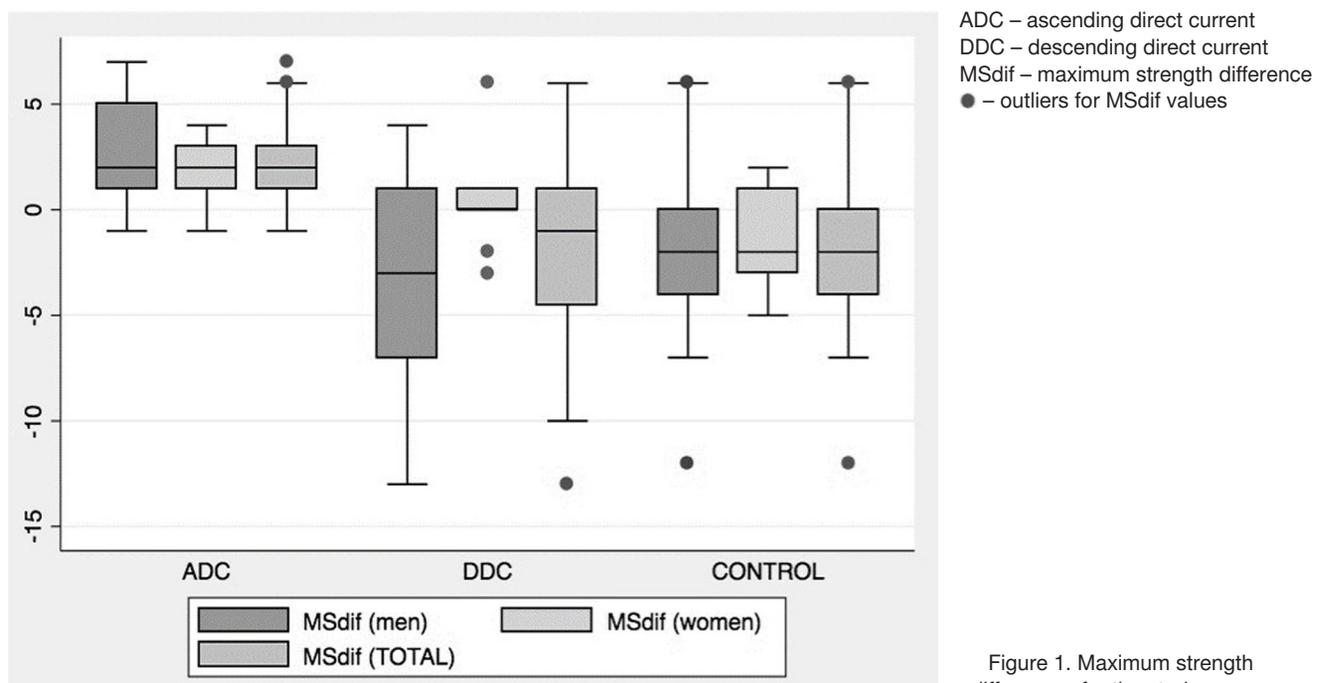* $p < 0.05$

ADC – ascending direct current
DDC – descending direct current
MSdif – maximum strength difference
● – outliers for MSdif values

Figure 1. Maximum strength differences for the study groups

the control group (p = 0.0000). However, Dunn's pairwise comparison test did not show statistically significant differences between the DDC and control groups (p = 0.3700). The analysis with Dunn's pairwise comparison test by sex revealed a statistically significant difference. Comparing the MSdif between men ADC and DDC groups (p = 0.0003) and comparing men between ADC and control (p = 0.0011), Dunn's pairwise test reported no statistically significant differences between DDC and control (p = 0.0979). Dunn's pairwise comparison test by sex for women showed a statistically significant difference when comparing MSdif between ADC and DDC (p = 0.0458), and comparing ADC with control (p = 0.0002). Dunn's pairwise test did not show statistically significant differences between women in the DDC and control groups (p = 0.3238).

Discussion

The objective of the study was to investigate the effects of ADC and DDC on muscle strength, evaluated by hand dynamometer. Literature suggests that DC is capable of promoting or inhibiting nervous system activity when applied in longitudinal galvanic therapy form, although the available evidence is scarce, with only a few studies that have tried to investigate these effects [7]. Some works suggest changes in motor threshold when using central or peripheral longitudinal galvanic therapy, reinforcing the idea of excitability or inhibition [12]. Not in vain has been to consider DC to influence the nervous system activity in transcranial applications, thus modulating behavioural disorders or favouring nervous system activation in neurological conditions [35–39].

The framework of this experimental design was attempted to evaluate the effectiveness of ADC and DDC on neuromuscular activity, specifically through the faculty to develop maximum grip strength. Muscle contraction is an excellent reflection of nervous system efferent activity, with a direct dependence between them. Any change in efferent nerve conduction will be reflected in muscle strength if these modifications are important [19–21].

Statistical analysis of secondary variables indicates that the compared groups were homogeneous. When analysing MSdif data after galvanic therapy session application, statistically significant changes were observed. MSdif values for the ADC group revealed an increase in strength in the manual dynamometry test among men and women ($p = 0.0001$) compared with the DDC group and the control group. The increase was 8.9% for the group, 6.7% for men, and 9% for women, which is interesting if one considers one session. The above could support the theory of facilitating the nervous system activity to induce a decrease in motor threshold [7]. The results also show a decrease in MSdif for the DDC group, both among men and women, compared with the control group, but without statistically significant differences between them. These results would support the existing theory and research suggesting that longitudinal galvanizing applications (Leduc effects) would facilitate the nervous system activity. The neurophysiological explanation for this effect is not entirely clear, although it is presumed that the electrode arranged proximally (cathode or anode) would be responsible for neural activity changes, mediated by its polar effect [7, 12]. In this way, the cathode, by its negative polarity, would generate an electrochemical environment that would facilitate the discharge of the nervous system (afferent and efferent), altering the potential of the resting membrane, taking it to a lower electronegativity, condition that tends to an ease discharge of excitable tissues. The anode, with its positive polarity, would have a hyperpolarizing effect [1, 7, 39]. Strength increase would then be supported by neurophysiological mechanisms that would result in the facilitation of nerve conduction, allowing the development of more action potentials at the dynamometry test time [1].

The reason that led researchers to perform galvanic therapy on the forearm is the lower skin thickness and adiposity, ensuring an effective penetration on underlying excitable tissues [38, 39]. However, considering the results obtained, the depth would not be an influencing factor for peripheral longitudinal applications compared with transverse galvanic therapy [7, 36]. In the DDC group, it was not possible to support the results of an inhibitory effect compared with the control group, although there was a tendency to a decrease. It is interesting to note that neither of the two groups showed an increase in strength. It is possible to ask some questions whether dose or sessions numbers are enough to achieve an inhibitory effect on the nervous system. The current dose was based on the safety parameters suggested by the literature to avoid injuries [7, 38, 39]. It may be possible that the inhibitory effects of longitudinal galvanic therapy require longer treatment times and/or intensities (mA · min), on the basis of Arnoldt Schultz law, which indicates that the physiological effect is directly proportional to the dose of applied energy [1, 7]. Another question is whether any of the other polar effects of the anode, located at the proximal level, is the real cause of excitatory variations or hinders them. It is documented, for example, that a decrease occurred in blood circulation with haemostasis at the anode [7]. Does this affect the nervous system activity?

Limitations

A limiting factor in the study was the sample size, which, although it is high, was determined by convenience. Moreover, the study is not characterized by a greater age variability, so the results obtained may not necessarily be extrapolated for other populations. Perhaps another dose is required to achieve the effects on the nervous system, considering that the strength for manual dynamometry differs with age.

Conclusions

The results indicate that ADC application can favourably influence the development of maximum strength in a manual dynamometry test for a treatment session (8% increase). These findings could be clinically interesting and could be applied in neurological or musculoskeletal conditions that imply strength alteration, always considering a structural indemnity of the nervous system; they could also find ergogenic applications in sports, so it is proposed to initiate research in these areas. Likewise, more designs that include more treatment, major sample size and follow-up sessions to assess these changes should be carried out. The proposal is to continue developing research in relation to DC applications, taking the present work as a basis, and improving dosimetry, number of sessions or study population in new designs. Favourable changes in grip strength obtained with ADC application could mark the beginning of an investigation line in electrotherapy and renew DC knowledge.

Disclosure statement
No author has any financial interest or received any financial benefit from this research.

Conflict of interest
The authors state no conflict of interest.

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