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Evaluation of pulsed electromagnetic field therapy to improve muscle strength and functional aspects in the elderly: A pilot study

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ABSTRACT

Backgroung: Sarcopenia has been defined as a progressive and generalized disorder of skeletal muscle that involves accelerated loss of muscle mass and function. The prevalence of sarcopenia worldwide is up to 15% in healthy elderly, approximately 76% of acutely hospitalized elderly patients, and up to 69% of patients admitted for post-acute geriatric rehabilitation. The loss of muscle mass results in serious consequences and several chronic diseases and senility, characterized by functional losses, muscle weakness, loss of independence and increased risk of falls and death. Sarcopenia has been defined as a progressive and generalized muscle disorder. Here we investigate the effects of PEMF in muscle strength and functional capabilities of elderly sarcopenic patients. **Methods**. Fifteen elderly people of both sexes, aged between 65 and 80 years old, classified according to the degree of muscle weakness. The participants were submitted to PEMF therapy in 12 sessions three times a week with the following parameters. In the first two sessions, only submaximal contraction was applied during 30 min with a frequency of 5 Hz at the sport mode of the equipment. In the following 10 sessions we used cycles of Submaximal contractions – frequency of 5 Hz with 5s duration and Supramaximal contractions – frequency of 30 Hz with 5s duration. The intensity of the equipment was adjusted according to the sensitivity of the patient and session duration was 30 min. **Results**. the TUG functional tests showed a significant reduction in execution time, with an initial average of 40 ± 10s to 22 ± 6s after treatment sessions. The average increase in muscle strength was 27 ± 9% after PEMF treatment. **Conclusions**. This case series report is the first in the world scientific literature to demonstrate the effectiveness of PEMF (Supramaximus™) therapy in gaining muscle strength and functionality in elderly sarcopenic patients. PEMF therapy, at least for the treatment of sarcopenia in the elderly, can be considered as the definitive evolution of electrical currents, with greater effectiveness and acceptance by the patient.
Keywords: Sarcopenia; Pulsed electromagnetic field; Aging; PEMF; Geriatrics.

BACKGROUND

The human being's remarkable ability to quickly adapt to constantly changing environmental and internal cues is vital to the health and survival of the organism. Most notable in human aging are changes in physiology and body composition, such as changes or redistribution in muscle and fat mass, even as total body weight remains unchanged(1).

In Human Beings, muscle mass remains relatively stable during early life, but after the age of 30, a natural process of muscle mass reduction begins at a rate of 0.5 to 1.0% per year(2). With the aging process, the impaired balance between protein synthesis and proteolysis in skeletal muscle results in a progressive decline in skeletal muscle mass, strength and function and is defined as sarcopenia(3). As the strength of the limb muscles and respiratory muscles gradually decreases, normal physical functions and activities such as breathing, standing, walking, and running will also decrease(3). On average, peak strength decreases by 20-40% between ages 30 and 80. The loss of muscle mass results in serious consequences and various chronic diseases and senility, characterized by functional losses, muscle weakness, loss of independence and increased risk of falls and death(4).

Sarcopenia has been defined as a progressive and generalized disorder of skeletal muscle that involves accelerated loss of muscle mass and function(5). In terms of human health, sarcopenia is associated with increased adverse outcomes including falls(6), functional decline(7), frailty and mortality(8). From a financial point of view, sarcopenia directly increases healthcare costs in society(9,10). The prevalence of sarcopenia worldwide is up to 15% in healthy elderly(11), approximately 76% of acutely hospitalized elderly patients(12-14), and up to 69% of patients admitted for post-acute geriatric rehabilitation(15). Thus, preventing or reversing sarcopenia is an important approach in healthy aging, both from an individual and societal point of view.

Widely accepted diagnostic criteria for sarcopenia require measurements of 3 components: muscle mass, muscle strength, and physical performance(16,17). Although the algorithm and testing tools have undergone some changes over the last decade, the main components remain the same. The components are not only applied for diagnosis and determination of severity, but also for monitoring the development of sarcopenia.

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To date, physical activity, with a focus on resistance (strength) training, is endorsed as a first-line therapy for managing sarcopenia[18]. Randomized controlled clinical studies have shown positive effects of resistance training on muscle mass, muscle strength and physical performance[19,20]. Such protocols remain as a reference standard for the prevention and treatment of sarcopenia in the elderly, but some technological innovations already available on the market such as the Pulsed Electromagnetic Field (PEMF) technology may represent an important advance for the situation.

Pulsed Electromagnetic Field (PEMF)

PEMF uses alternating magnetic fields, based on the law of electromagnetic induction, promotes electrical currents that depolarize the neuromuscular tissue, causing supramaximal contractions[21-23]. Motor neurons are activated due to their large diameter and therefore lower resistance compared to other types of neurons. Since the nociceptors are not activated, the application of magnetic stimulation is not painful[24,25].

PEMF and Muscle Hypertrophy

According to Duncan & Dinev[26], in an in vivo study carried out in a porcine experimental model, PEMF was able to induce hypertrophic muscle alterations after 2 weeks of treatment. The authors report an increase in muscle mass density of 20.56%. In the same study, an increase in muscle fiber density (hyperplasia) of 8.0% was observed. Mean individual muscle fiber size increased by 12.15% 2 weeks after treatment, while the control group showed no significant changes in fiber density or hyperplasia. The authors suggest that PEMF can be used for non-invasive induction of muscle growth. Pulsed Electromagnetic Field (PEMF) technology is an innovative technology that has shown important results in gaining strength and muscle mass. Here we performed a pilot study in order to investigate the concept that PEMF technology is capable of producing gains in muscle strength and functionality in the elderly, contributing to the prevention of sarcopenia.

METHODS

So far, 15 elderly people of both sexes, aged between 65 and 80 years old, classified according to the degree of muscle weakness, have been treated. The elderly attended underwent a standard elderly health anamnesis and received the standard treatment of muscle stretching, warm-up and PEMF training. Because it is a university extension project, there was no control group and the inclusion and exclusion criteria were limited to cardiovascular diseases or some inability to move the lower limbs. The pulsed electromagnetic field generator Supramaximus™ (Adoxy Inc. Sorocaba – Brasil) was used in the study.

Clinical Anamnesis

Clinical evaluation: medical history and physical examination were performed. Vital Signs and Anthropometry included systolic and diastolic blood pressure in the sitting position, heart rate (pulse), axillary temperature in °C, height and weight measurements, and body mass index (BMI). Blood pressure was considered normal within the following limits: 90-139 mmHg for systolic and 50-89 mmHg for diastolic. Cardiac frequency within 50-100 bpm was considered normal. Participants with BMI in the range of 18 to 33 kg/m2 were accepted.

Inclusion Criteria

Participants were accepted if they could be included in the following criteria: Male or female research participants aged 65 years or older and aged 80 years or less; Preserved cognitive capacity; No other significant illnesses that may impact their participation in the study, in accordance with the rules defined in the Protocol, and assessments; Cognitive function able to understand the nature and purpose of the study, including risks and adverse effects and with the intention to cooperate with the researcher and act in accordance with the requirements of the entire trial, which is confirmed by signing the Consent Form Free and Enlightened.

Exclusion Criteria

Participants were excluded if the present: Severe cardiovascular or cerebrovascular disease; Participant with current evidence of clinically significant diseases, of origin: gastrointestinal, cardiovascular, hepatic, renal, pulmonary, or other that prevent the individual's participation in the study and/or that, in the judgment of the main researcher, expose the research participant to additional risk than normally anticipated such as lupus erythematosus; Drug addiction, including alcohol; Performed any previous treatment for the lesion in question that, in the judgment of the main researcher, may interfere with the study objectives; BMI below 18 or above 33 kg/m2; The research participant has any condition that prevents him from participating in the study in the judgment of the investigator.

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Assessment of gait, postural balance and functional mobility

Gait analysis was performed using the SMART-D 140® program (BTS Engineering, Milan, Italy) with a sampling rate of 100 Hz, eight cameras sensitive to the infrared spectrum and the SMART-D® (BTS Engineering, Milan, Italy) with 32 analog channels. All participants wore swimsuits to facilitate the placement of the reflective markers.

After the anthropometric measurements (height, weight, lower limb length, distance between the femoral condyles or diameter of the knee, distance between the malleoli or diameter of the ankle, distance between the anterior superior iliac spines or thickness of the pelvis and vertical distance on the sagittal plane in the supine position between the anterior superior iliac spine and great trochanter), passive markers were placed at specific reference points directly on the skin to evaluate the kinematics of each segment of the body, as described by Davis et al.[15] After placement of the reflective markers, the participants were instructed to walk along a 10-m track at comfortable pace. At least six trials were performed (two sets of three). For each participant, three out of the six trials that were consistent in terms of gait pattern were considered for analysis. All data were exported in .txt format to electronic spreadsheets and tabulated using Microsoft Office Excel® 2013 (Redmon, IL, USA).

The following were the spatiotemporal variables: velocity (m/s) (mean velocity of progression), step length (m, longitudinal distance between the point of initial contact of one foot and the point of initial contact of the contralateral foot), step width (m, distance between the rear end of the right and left heel centerlines along the mediolateral axis) stance phase (% gait cycle that begins with initial contact and ends with toe-off of the same limb) and double support (s, period of time when both feet are in contact with the ground).

The Six-Minute Walk Test (6 MWT) was performed to determine the degree of mobility and the speed to be used on the treadmill. This is a simple test developed to evaluate functional capacity through the measure of the distance traveled in a given period of time. Each volunteer was instructed to walk at a self-selected pace without running for six-minutes along a 30-m track. The volunteer was allowed to vary the pace and stop to rest, if necessary. The test was performed twice: once for familiarization and once to record the distance travelled, which was transformed from m/s to km/h to determine the treadmill training speed. A one-week interval was respected between the first and second tests. Blood pressure and heart rate were monitored to ensure cardiovascular stability.

Assessment of functional mobility: Timed Up and Go Test (TUG)

The Timed Up and Go (TUG) test is widely used to assess functional mobility and dynamic functional balance. This test also quantifies, in seconds, the time that the individual performs the task, that is, in how many seconds he gets up from a standardized chair without support and arms, walks three meters, turns around, goes back to the chair and sits down again. Participants were instructed to perform the test at a self-selected speed in a safe manner.

Evaluation of Muscle Strength by Dynamometry

Muscle strength assessments of lower and upper limbs were performed with the E-lastic Computerized Dynamometry System. It is a dynamometer that can be attached to any part of the body, based on a load cell capable of evaluating the force produced by a muscle, as well as the speed and acceleration of the limb movement. The system is capable of transmitting data in real time to a cell phone or notebook via Bluetooth and even remotely via the internet to a central.

A series of 03 maximum contractions (triplicate) were performed for each evaluated member, being extension and flexion of the knee and trunk. The force value was taken into account the greatest force produced in the 3 attempts.

The system has a set of bracelets that adapt to the member, not causing any kind of discomfort or discomfort, except for the production of the participant's own strength.

Pulsed Electromagnetic Field Treatments

The participants were submitted to PEMF therapy in 12 sessions three times a week with the following parameters. In the first two sessions only submaximal contraction was applied during 30 min with a frequency of 5 Hz at the sport mode of the Supramaximus™ equipment. In the following 10 sessions we used cycles of Submaximal contractions – frequency of 5 Hz with 5s duration and Supramaximal contractions – frequency of 30 Hz with 5s duration. The intensity of the equipment was adjusted according to the sensitivity of the patient and session duration was 30 min.

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RESULTS

Individual Muscle Force Increases

Figure 1A demonstrate the individual increases in muscle force quantified by the dynamoter system. Absolute values were used and as we can observe, all participants presented positive variations in muscle strength. Figure 1B shows the average and standard deviation of the group, concerning on muscle strength before and after pulsed electromagnetic therapy of the elderly participants.

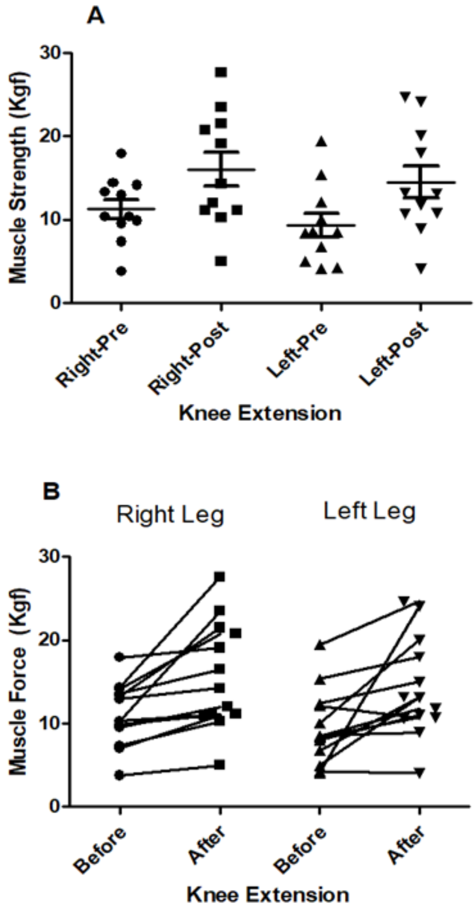

Figure 1. Individual values of Muscle force, before and after pulsed electromagnetic field therapy with Supramaximus in 13 elderly sarcopenic participants.

Differences (asymmetries) in Muscle Strength between Members

Figure 2 demonstrates the differences in muscle strength between the lower limbs of the treated elderly. We can observe that there were no significant differences regarding the differences in strength between the treated sides, before and after the electromagnetic field therapy. The average difference between limbs before treatment was approximately 2 Kgf, and after treatment it was 1.8 Kgf, demonstrating that the increase in muscle strength occurred linearly for both treated sides.

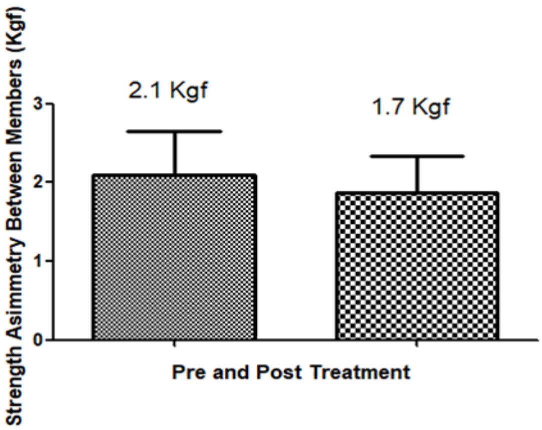

Figure 2. The graph quantitatively demonstrates the differences in muscle strength between the right and left limbs, before and after treatment with an electromagnetic field.

TUG test

As can be seen in Figure 3, the TUG functional tests showed a significant reduction in execution time, with an initial average of 40 ± 10s to 22 ± 6s after treatment sessions with pulsed electromagnetic field therapy (PEMF). of gait and balance demonstrated an average reduction of 47% after treatment with PEMF for 10 weeks.

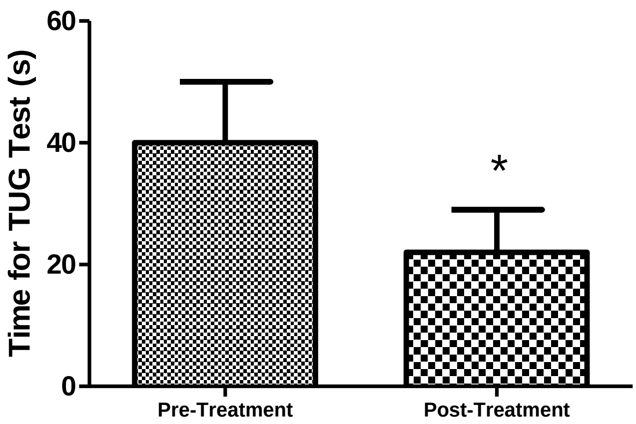

Figure 3. Shows the time values for performing the TUG Test (time up and go) which evaluates functionality in the elderly.

DISCUSSION

Several studies have shown that humans are unable to fully activate muscles voluntarily as the strength of muscles to contract is limited by the firing rates and conductivity of neural pathways[27-29].

PEMF generates impulses that are independent of brain function, and with a frequency so fast that it does not allow for the muscle relaxation phase, characterizing tetanic contractions. To simulate muscle

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workload conditions, the equipment modulates the PEMF emission in submaximal modes, from 1Hz to 10Hz and supramaximal mode, from 10Hz to 100Hz, with ON time in seconds that can also be parameterized (0 to 60s). In our study we combined both, low and high frequency stimulation and we were able to observe significant muscle strength after 12 sessions. The adopted protocol intended to provide an initial adaptation to the new sensations to the eldery patient. The training protocol adopted in this study was significantly efficient for gaining muscle strength in treated patients. As can be seen in figures 1A and 1B, all participants showed a positive result in strength increment after the 12 treatment sessions. A limitation of our study is that strength gain was not, at this time, compared with another type of intervention. A large study is currently being developed for comparison purposes.

PEMF has the ability to generate sustained supramaximal contractions for several seconds, which significantly increases stress/workload if muscle adaptation occurs[30]. The recommended treatment for sarcopenia of the elderly is physical activity, especially focused on resistance muscle strengthening training. However, the methods used to date to gain strength and muscle mass focus on bodybuilding exercises or classic electrical currents. In both cases, we must consider the difficulties and physical, social and even sensitivity limitations of the elderly person, which ends up leading to low adherence to treatment and reduced chances of success. The resistance of elderly patients to attending gyms full of young people is well known, due to the natural constraints of older age in an environment that is not recognized as their own. In addition, most traditional fitness and weight training centers do not have the more personalized follow-up required by an elderly person with sarcopenia. On the other hand, there are the classic electric currents, used in physiotherapy, for muscle strengthening. In this case, the elderly patient is faced with another type of limitation, now related to sensitivity. The elderly patient, notably, presents increased sensitivity to painful stimuli, or even electrical currents, making the treatment unbearable. Data from our research group (unpublished) show that the degree of pain or hypersensitivity induced by electrical currents in elderly patients treated with this type of therapy, on a visual analogue scale (0 to 10), reaches values between 7 and 9. In the treatment with pulsed electromagnetic field, using the same scale, the degree of hypersensitivity or even pain did not exceed level 03, demonstrating a significantly greater adaptation or acceptance of therapy with pulsed electromagnetic field.

The results obtained in the functional tests also revealed a significant improvement, both in the execution time of the tasks and in the resourcefulness to carry them out. The improvement in muscle strength is directly related to the reduction of imbalances and falls in the elderly.

A second important point observed in Figure 03 was the reduction of muscle asymmetry in terms of strength. Before treatment, important asymmetries between limbs were observed, of the order of 2.1 kgf. Such asymmetries were reduced to 1.7 Kgf on average, representing an improvement of 20%. It is important to point out that such a reduction in muscle asymmetries was obtained with standard treatment, equally applied to both limbs, that is, no specific protocol was performed to strengthen a weaker limb.

CONCLUSION

This case series report is the first in the world scientific literature to demonstrate the effectiveness of PEMF (Supramaximus®) therapy in gaining muscle strength and functionality in elderly sarcopenic patients. PEMF therapy, at least for the treatment of sarcopenia in the elderly, can be considered as an important alternative to electrical currents, with greater effectiveness and acceptance by the patient.

Authors Contribution: Patricia Sardinha Leonardo, Rodrigo Alvaro B. Lopes-Martins and Claudia Santos Oliveira – team leaders of the study; Katiele Rodrigues da Silva Cardoso, Bruno Oliveira Silva, Ruan Oliveira Silva, Helen Cristina de Araújo Silva, Paulo Ricardo Pinheiro França, Beatriz Nascimento Souza, Isabela Laine, Carly de Faria – Protocol and tests execution. Alberto Souza de Sá Filho – Critical Reading of the manuscript;

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