ARC Journal of Research in Sports Medicine
Volume 3, Issue 2, 2018, PP 19-24
www.arcjournals.org

Electrical Sensory Threshold and Current Tolerance Response to Neuro-Muscular Electrical Stimulation after Application of Thermal Agents on Apparently Healthy Undergraduate Students

Ahanonu Odirachukwu, Msc[1], Mong U Emeka, PhD[2], John O Davidson, Msc[1,*], Dim A Peter, Msc[1], Onuorah Ogochukwu C, Msc[1], John N Jeneviv, Msc[3]

[1]*Department of physiotherapy, Federal Teaching Hospital, Abakaliki, Nigeria*

[2]*Department of human kinetics and Health Education, Ebonyi State University, Abakaliki, Nigeria*

[3]*Department of Medical Rehabilitation, Faculty of Health Sciences and Technology, University of Nigeria, Enugu Campus, Nigeria*

Corresponding Author: *John Davidson Okwudili, *Department of physiotherapy, Federal teaching hospital, Abakaliki, PMB 102 Ebonyi State, Nigeria,* ***Email:*** *davidsonokwudili@yahoo.com*

Abstract

The purpose of this study was to evaluate the electrical sensory threshold and current tolerance to NMES after application of cryotherapy and infra-red radiation. The study involved eighty apparently healthy undergraduate students who were randomly assigned to two treatment groups. Group A received cryotherapy with ice packs wrapped around the tibialis anterior muscle of the dominant leg for10 minutes while group B received infra-red radiation placed 50cm away from the tibialis anterior muscle of the dominant leg for 12 minutes. Sensory threshold and current tolerance were determined using an electrical stimulator machine before and after treatment. There was a within group significant difference in sensory threshold and current tolerance before and after application of cryotherapy and infra-red radiation (P=0.01). There was a between group significant difference in sensory threshold (P=0.01) and current tolerance (P=0.02) to NMES after application of cryotherapy and infra-red radiation. Sensory threshold and current tolerance are increased by cryotherapy and decreased by heat. Therefore, sports medicine experts, clinicians and physiotherapist should consider using thermal agents (cryotherapy) before muscle stimulation using NMES to aid tolerate more intensity of current required for maximal muscle strengthening while training and rehabilitating weak muscles.

Keywords: *Neuromuscular stimulation, Thermal agents, Current tolerance, Sensory threshold.*

1. INTRODUCTION

Strength training is an essential part of training programs for many types of competitive athletes, for rehabilitation and the prevention of orthopedic or muscular injuries, as well as for older adults [1]. It can also be of value to all interested in optimizing health and longevity [2]. The benefit of muscle training include increase in muscle size, increasing maximum muscle strength and endurance, and for improving physical performance while preventing muscle atrophy [3, 4]. Both voluntary isometric contraction and Neuromuscular Electrical Stimulation (NMES) have been regarded as valid means of strength training for improving muscular strength and/or facilitating rehabilitation [5, 6]. NMES is the application of an electric current pulse on motor points through surface electrodes to induce depolarization of motor axons that leads to muscle cells excitation and contraction [7]. Electrical stimulation can attain much higher levels of activity over time than any exercise regime and, therefore, the adaptive potential of the system is challenged to its limit [8]. High levels of activity can be imposed on the target muscles by NMES from the beginning of stimulation unlike the case of exercise which might be limited by the central nervous system, cardiovascular and other systems [8].

Furthermore, research on the use of NMES has found out that electrical stimulation is a relevant and efficient compliment to voluntary resistance training protocol for muscle strength improvement [9, 10] or used as an alternative when time available for strengthening program is limited [11]. Although the successful use of Electrical stimulation in augmenting strength training and muscle rehabilitation has been documented, a major limiting factor in its use is the discomfort and pain associated with electrically produced contractions [12]. The involuntary high contractile forces elicited by electrical muscle stimulation can indirectly provoke increased pain, apprehension, or fear, resulting in added discomfort associated with NMES [13]. These discomfort and pain during NMES generally limit the tolerated stimulus amplitude and, in turn, the strength of the electrically induced contractions [14]. Therefore, individuals with low sensory threshold level may not be able to tolerate progressively increasing current intensity necessary for effective strength gains in the muscle using NMES [15].

Besides, thermal agents such as cold agents (cold/ice packs, cryopressure garments, vapocoolant sprays) and superficial heat (hot packs, paraffin, infrared lamps, etc.) are generally used to control pain, increase circulation, enhance healing and increase soft tissue extensibility [16]. Studies have suggested that the application of cold or heat alters the sensory pain perception through sensory nociceptive pathways [17]. Thermotherapy is the therapeutic application of heat. It is used primarily to control pain, increase soft tissue extensibility, increase circulation and accelerate healing process [18]. The use of heat has also been shown to elevate the pain threshold and increase nerve conduction velocity [19]. Heat therapy can either be superficial or deep and can be transferred into the body by conduction, convection, and radiation. Several heat agents are available for heat application to tissues. Deep heating agents, such as continuous uninterrupted ultrasound and continuous shortwave diathermy, increases the temperature of tissues at depths of 3 to 5 cm. Superficial heating agents, such as hot packs, air-activated heat wraps, warm whirlpool, fluidotherapy, Infra-red lamp and paraffin, primarily increase the temperature of the skin and subcutaneous tissue with less of an effect on deeper structures. Heat from superficial heating agents generally penetrates to depths of less than 2 cm from the surface of the skin. Subcutaneous tissue that is well vascularized reaches its maximum temperature increase within 8 to 10 minutes of application [19]. Skin and subcutaneous tissue temperatures increase 5°C to 6°C after 6 minute and are maintained up to 30 minutes after application. Intervention duration of 15 to 30 minutes is necessary for an increase in muscle temperature of 1°C at depths up to 3 cm [19].

Infrared lamps emit electromagnetic radiation within the frequency range that gives rise to heat when absorbed by matter. There are two types of infrared lamps; luminous or visible infrared lamp and non-luminous infrared lamp. Luminous infrared lamps are used in clinical settings for therapeutic purposes. The heat emitted is absorbed within the first 1 to 3mm of human tissue and is thus able to pass through the skin to interact and have effect on subcutaneous nerve endings [16].

The use of heat to control pain has been attributed to the gating of pain transmission by activation of cutaneous thermoreceptoros, indirectly be the result of improved healing, or reduced ischemia [16]. Increasing skin temperature may also reduce the sensation of pain by altering nerve conduction velocity [16].

Cryotherapy is the therapeutic application of a cold substance to the body that removes heat from the body leading to decreased tissue temperature [18]. Techniques such as ice packs, cold gel packs, ice immersion, ice massage, vapocolant spray and whirlpool are used to administer cryotherapy. The effect of cryotherapy in pain reduction and analgesia has been well documented [20].

However, the limiting factor of discomfort and pain has led to reduced adherence and lack of tolerance to treatment using NMES [21-23]. It becomes necessary to develop protocols or strategies to minimize the discomfort and pain accompanying electrical muscle stimulation in other to improve adherence and tolerance to NMES. From available literature only two studies have investigated the effects of thermal agents (superficial heat or cold) on the pain thresholds and current tolerance to NMES [17, 24]. Therefore, there is still paucity of data on the effects of cryotherapy and superficial heat used prior to electrical muscle stimulation on sensory threshold and current tolerance. More empirical evidence is needed to establish the effects of thermotherapy on the pain threshold and current tolerance to NMES.

Hence, this study sought to answer the following research questions: What is the difference in electrical sensory threshold response and current tolerance response to NMES before the application of cryotherapy and Infra-red? What is the difference in electrical sensory threshold response and current tolerance response to NMES after the application of cryotherapy and Infra-red? What is the difference in electrical sensory threshold response and current tolerance response to NMES after the application of cryotherapy compared to Infra-red radiation?

2. Materials and Methods

2.1. Design

A pretest- posttest randomized trial to examine the effect of thermal agents (cryotherapy or infra-red radiation) application on the current tolerance and electrical sensory threshold responses to NMES.

2.2. Participants

Eighty (80) undergraduate students who volunteered to participate in the study were randomly assigned to either of the two treatment groups: Group A (cryotherapy) and Group B (infrared lamp radiation) using the fish bowl method. Inclusion criteria were: Age 18 years and above, willingness and availability to participate. Exclusion criteria were: Presence of the following conditions on the dominant lower extremity-local infection, unhealed muscle, tends on or bone injury, systemic infection, exposed metal implants, cancerous lesions. Local cardiovascular and/or neurologic inhibition, history of epilepsy, previous adverse reaction to electrical stimulation, previous adverse reaction to superficial cold or heat. An ethical approval was sought and obtained from the institutional research and ethics committee before recruiting the subjects. Also an informed consent was gained from the participants before commencement of data collection. Consent was also sought and obtained from one of the participant to display his photograph for an illustration.

2.3. Instruments

BTL Combi Professional (BTL Medical Technologies Inc, BTL-4816S, Canada): This was used to determine the electric sensory threshold and current tolerance of the participants. This is a muscle stimulator machine with combined unit. It has two channels: one for electrotherapy and one channel for ultrasound. It has an intra rata reliability of 0.67 to 0.81[25].

***Beurer portable infra-red lamp (Beurer health and wellbeing, Model IL50, Ulm, Germany)*:** It is 11.8inch×15.7inch in dimension. This was used to deliver infra-red heat to the dominant leg.

***Medical history questionnaire*:** This is an adapted questionnaire consisting of10 item used to screen the participants for inclusion in the study [17].

3. Procedure

The purpose and procedure of the study was explained to the participants and they gave their consent to be part of the experiment via the informed consent form. A medical history questionnaire was used to identify the presence of any of the exclusion criteria. Treatment was carried out in the Exercise physiology laboratory. The participants were instructed to lie on a plinth in supine position with their dominant leg adequately exposed and placed on a pillow. The researcher cleaned the lateral aspect of the dominant leg (tibialis anterior muscle) using a cotton wool soaked with methylated spirit. Then, two self-adhesive electrodes (5 × 5 cm) interspaced 5 cm from each other, was placed on the tibialis anterior muscle of the dominant leg, beginning from the proximal tibia (see figure 1 below).

Figure1. *Set up showing electrode placement*

Using biphasic symmetrical pulses with 240 μsec duration and 50 pps frequency, beginning from 0 mA, the current amplitude was increased slowly at a rate of approximately 1 mA/s, and participants were asked to say “yes” when they first perceived the electrical current. That amplitude was recorded as the sensory threshold (mA). Then, the amplitude was increased in the same manner up to the highest level that the participants could tolerate without pain or discomfort. The amplitude was recorded as current tolerance (mA) [13, 26]. These values were recorded as pretest values. Then, group A participants received cryotherapy with ice packs wrapped around the stimulated dominant leg for ten minutes while participants in group B received infra-red lamp radiation placed 50cm away from the stimulated dominant leg for 12 minutes. Immediately after the treatment, the two groups received NMES as outlined above to determine their post treatment values for electrical sensory threshold and current tolerance responses. These values were recorded as posttest values.

4. Data Analysis

Descriptive statistics of mean and standard deviation was used to summarize data. Inferential statistics of t-test was used to test hypothesis. Alpha level was set at $P<0.05$.

5. RESULTS

80 participants (59[73.8%] males, 21[26.3%] females) were enrolled for the study. Table 1 below shows the demographic characteristics of the participants.

Table1. *Demographic characteristics of the participants*

Variable	Group A (Cryotherapy) (n=40) Ñ±SD	Group B (Infra-red radiation) (n=40) Ñ±SD
Age(years)	40.8±80	41.0±90
Height(m)	1.71±0.07	1.70±0.74
Weight(kg)	69.13±10.5	69.50±11
BMI	23.64±15.0	23.88±14.8

Ñ±SD= mean ± standard deviation

There was a within group significant difference in current tolerance and sensory threshold response to NMES (See Table 2 below).

Table2. *Within group comparison of electrical sensory threshold and current tolerance response to NMES*

	Pre (n=40) Ñ±SD	Post(n=40) Ñ±SD	Mean D	t-value	p-value
Group A (Cryotherapy)					
Sensory threshold (mA)	7.8±2.93	12.0±2.92	-4.08	-33.73	0.01*
Current tolerance (mA)	26.5±9.26	30.4±9.58	-5.48	-8.32	0.01*
Group B (Infra-red radiation)					
Sensory threshold (mA)	8.3±3.54	7.5±3.38	0.80	5.73	0.01*
Current Tolerance (mA)	26.9±9.48	24±8.47	3.03	6.73	0.01*

n=Total number of participants; Ñ±SD= mean ± standard deviation; Mean D= Mean deviation;= significance within group at p<0.05.*

Table 3 also showed that there was a between group significant difference in current tolerance and sensory threshold response to NMES.

Table3. *Between group comparison of electrical sensory threshold and current tolerance response to NMES*

	Cryotherapy (n=40) Ñ±SD	Infra-red radiation (n=40) Ñ±SD	Mean D	t-value	p-value
Sensory threshold (mA)	4.1±0.76	0.8±0.88	3.28	17.74	0.01*
Current tolerance (mA)	5.5±4.16	3.0±1.77	2.55	3.56	0.02*

*n=Total number of participants; Ñ±SD= mean ± standard deviation; Mean D= Mean deviation; *= significance between group at p<0.05.*

6. DISCUSSION

The result showed an increased sensory threshold and that participants tolerated more intensity of electric current during NMES after cryotherapy. There was also a significant difference in both electrical sensory threshold response and current tolerance response to NMES after cryotherapy application for 10 minutes. This significant difference in sensory threshold response to NMES after cryotherapy is in agreement with the findings of significant difference in electrical sensory threshold and current tolerance to NMES observed after cold packs was applied on the non-dominant fore-arm of 24 Turkish university students prior to electrical stimulation [24]. Also the result is in tandem with the findings of a study carried out in Australia which found out that a significant difference existed in the plateau current at baseline compared to the plateau current following the application of superficial cold and that of a significant difference in electrical sensory threshold when ice bags was applied to the dominant thigh of 15 participants for 20 minutes prior to electrical stimulation [17]. Similarly, Van Lumen et al in 2003 also recorded a significant difference in current tolerance to NMES after ice treatment was used on the dominant thigh of American adults [27]. The findings of this study might thus indicate that when cryotherapy is used prior to NMES, more currents will be required before electrical sensation will be felt and may also indicate a delay in discomfort. This may also suggest that individuals can tolerate more output intensity to NMES after cryotherapy and this may thus aid in achieving the desired current intensity required for the needed electrically induced contractions used for muscle strengthening.

However, the sensory threshold and current tolerance to NMES decreased after infra-red application. Participants tolerated less intensity of electric current after heat therapy. Findings showed there was a significant positive difference on electrical sensory threshold response and current tolerance response to NMES after infra-red lamp radiation application for 12 minutes. This result is in agreement to the observation of a positive difference in electrical sensory threshold and a decrease in current tolerance when hot packs was used on the non-dominant fore arm of Turkish students after the application of hot pack for 15 minutes [24]. This result is also similar to the findings of an increase in mean plateau current of 21% on electrical sensory threshold and a significant difference in the plateau current at baseline compared to the plateau current following the application of superficial heat at limit of tolerance when hot packs was used on the dominant tibialis anterior of American adults prior to transcutaneous electrical stimulation [17]. This finding may therefore indicate a faster response of electrical sensory threshold after the use of superficial heat and thus may lead to a quicker time of discomfort when NMES is being used for muscle strengthening. This may indicate that application of heat prior to neuromuscular electrical stimulation may reduce current tolerance and limit the generation of the desired current intensity required to elicit the electrically induced contractions needed for muscle strengthening.

Furthermore, between groups comparison showed that there was a significant difference in electrical sensory threshold and current tolerance response to NMES after application of cryotherapy and infra-red radiation. This result is similar to the findings of a study that revealed a significant difference when the effect of thermal agents on sensory threshold and current tolerance were compared [24]. The same study also observed that the most obvious effect on electrical sensory threshold and current tolerance was caused by hot pack. The finding of this study might imply that both thermal agents produce a response on electrical sensory threshold and current tolerance prior to use of NMES.

7. CONCLUSION

Individuals who use neuromuscular electrical stimulation as a means of strength training will be able tolerate more electrical current intensity, thus achieving the desired current intensity for strengthening the electrically induced contractions of the muscle after cryotherapy. Individual's sensory threshold to electric current decreases after heat application and may indicate an early stage of discomfort before the desired current intensity for strengthening muscles with electrical current is achieved. Therefore, clinicians, physiotherapist, individual fitness coaches and sports medicine experts should consider using thermal agents (cryotherapy) before muscle stimulation using NMES to aid tolerate more intensity of current required for maximal muscle strengthening while training and rehabilitating weak muscles.

REFERENCES

[1] Frohlich M, Emrich E and Schmidtbleicher D. Outcome effects of single-set versus multiple-set training. An advanced replication study. Res Sports med2010; 18:157-75.

[2] Fisher J, Steele J, Bruce-Low S and Smith D. Evidence-based Resistance Trainning Recommendations. MedicinaSportiva 2011; 15:147-162.

[3] American College of Sports Medicine. ACSM's position stand on Progression models in resistance training for healthy adults. Med. Sci Sports Exerc2009; 41: 687-708.

[4] Lee SH, Farrar RP. Resistance training induces muscle specific changes in muscle mass and function. J exercphysiol2003; 6:80-87.

[5] Morrissey MC. Electromyostimulation from a clinical perspective. A review. Sports Med 1988; 6:29-41.

[6] Hortobágyi T, Lambert NJ, Hill JP. Greater cross education following training with muscle lengthening than shortening. Med. Sci Sports Exerc 1997; 29:107-112.

[7] Rodriguez PO, Setten M, Maskin LP, Bonelli I, Vidomlansky SR, Attie S et al. Muscle weakness in septic patients requiring mechanical ventilation: Protective effect of transcutaneous neuromuscular electrical stimulation. J Crit Care 2012; 27:319.e1–319.e8.

[8] Pette D, Vrbova G. What does chronic electrical stimulation teach us about muscle plasticity? Muscle Nerve 1999; 22:666-677.

[9] Bax L, Staes F, Verhagen A. Does Neuromuscular Electrical Stimulation Strengthen the Quadriceps Femoris? A Systematic Review of Randomized Controlled Trials. Sports Med2005; 35:191-212.

[10] Gondin J, Cozzone P, Bendahan D. Is high-frequency neuromuscular electrical stimulation a suitable tool for muscle performance improvement in both healthy humans and athletes? Eur J ApplPhysiol 2011; 111:2473-87.

[11] Deley G, Comett C, Fatnassi C, Paizis C, Babault N. (2011). Effects of combined electromyostimulation and gymnastics training in prepubertal girls.J Strength Cond Res2011; 2:520-26.

[12] Liebano RE, Rodrigues TA, Murazawa MT, Ward AR. The influence of stimulus phase duration on discomfort and electrically induced torque of quadriceps femoris. Braz J Phys Ther 2013; 17:479-486.

[13] Delitto A, Strube J, Shulman D, Minor D. A study of discomfort with electrical stimulation. Phys Ther 1992; 72:410-421.

[14] Laufer Y, Tausher H, Esh R, Ward R. Sensory transcutaneous electrical stimulation fails to

decrease discomfort associated with neuromuscular electrical stimulation in healthy individuals. Am J Phys Med Rehabil 2011; 90: 399-406.

[15] Vivodtzev I, Debigare R, Gagnon P, Mainguy V, Saey D, Dube A. Functional and muscular effects of neuromuscular electrical stimulation in patients with severe COPD: a randomized clinical trial. Chest2012; 141:716-725.

[16] Cameron MH. Thermal agents: cold and heat. In: Cameron MH, ed. *Physical agents in* rehabilitation: from research topractice. 3rd ed. Saunders, Elsevier; 2009:131-176.

[17] Jelinek HF and Barnden R. Superficial cold and heat application during transcutaneous electrical nerve stimulation maynot change perceived sensation of pain. The Internet Journal of Pain, Symptom Control and Palliative Care 2012; 9.DOI:10.5580/2aa6.

[18] Nadler SF, Weing and K, Kruse RJ. The physiologic basis and clinical applications of cryotherapy and thermotherapy for the pain practioner. Pain Physician2004; 7:395-399.

[19] Behrens B, Beinert H. Physical Agents: Theory & Practice 3rded. F.A Davies;2014.

[20] Algafly AA, George KP. The effect of cryotherapy on nerve conduction velocity, pain threshold and pain tolerance. Br J Sport Med2007; 41:365-369.

[21] Piva SR, Goodnite EA, Azuma K, Woollard JD, Goodpaster BH, Wasko MC et al. Neuromuscular Electrical Stimulation and Volitional Exercise for Individuals with Rheumatoid Arthritis: A Multiple-Patient Case Report. physther 2007;87:1064-1077.

[22] Maddocks M, Halliday V, Chauhan A, Taylor V, Nelson A, Sampson C et al.Neuromuscular electrical stimulation of the quadriceps in patients with non-small cell lung cancer receiving palliative chemotherapy: a randomized phase II study. BMC Palliat care2013; 30; 8(12): e86059. doi: 10.1371/ journal. pone.0086059.

[23] Windholz T,Swanson T, Vanderbyl BL, Jagoe RT.The feasibility and acceptability of neuromuscular electrical stimulation to improve exercise performance in patients with advanced cancer: a pilot study. BMC Palliat care.2014 .doi: 10.1186/1472-684X-13-23

[24] KarakayaaI, Güneyb O, Aydınc Y, Karakayaa M.Effects of thermal agents on electrical sensory threshold and current tolerance when applied prior to neuromuscular electrical stimulation. J Back and Musculoskelet Rehabil2014; 27:191–196.

[25] Ellaway P, Catley M. Reliability of the electrical perceptual threshold and Semmes-Weinstein momofilament test of cutaneous sensibility. Spinal Cord 2013; 51:120-125.

[26] Maffiuletti NA. Physiological and methodological considerations for the use of electrical stimulation. Eur J Appl Physiol 2010; 110:223-234.

[27] Van Lunen B, Carroll C, Gratias K, Straley D. The clinical effects of cold application on the production of electrically induced invol-untary muscle contractions. J Sport Rehabil 2003; 12:240-248.

Citation: *Ahanonu Odirachukwu, Mong U Emeka, John O Davidson, Dim A Peter, Onuorah Ogochukwu C, John N Jeneviv, Electrical Sensory Threshold and Current Tolerance Response to Neuro-Muscular Electrical Stimulation after Application of Thermal Agents on Apparently Healthy Undergraduate Students. ARC Journal of Research in Sports Medicine. 2018; 3(2):19-24.*