DOI: 10.1590/1809-2950/e21008423en

INTEGRATIVE REVIEW

Neuromuscular Electrical Stimulation in Facial Aging: an Integrative Literature Review

Estimulação Elétrica Neuromuscular no Envelhecimento Facial: uma Revisão Integrativa da Literatura

Estimulación Eléctrica Neuromuscular en el Envejecimiento Facial: Revisión Integradora de la Literatura

Márcia Cristina Dias Consulin[1]*, Louise Idalgo Vasques[2]*, Gislaine Ricci Leonardi[3]

*All authors share first-authorship credits.

ABSTRACT | Despite of being a natural physiological process, aging is considered a degenerative process with evident effects on aging skin, such as reduced elasticity, wrinkles, reduced facial fat and muscle tone, sagging, changes in facial contour, and sarcopenia on the face. These changes can generate social stigma, suffering, and psychological discomfort for the patient. Thus, this study aimed to evaluate the effectiveness of Neuromuscular Electrical Stimulation (NMES), a technique used in physical therapy for muscle training, in attenuating the signs of facial aging. For this purpose, a scientific survey of publications indexed on the Medline (PubMed), CINAHL, Embase, PEDro, Lilacs, ERIC, Scopus, Web of Science, and Google Scholar databases was conducted and, based on pre-established criteria, two relevant publications for the topic were selected for discussion. The scientific literature regarding the use of NMES to attenuate the signs of aging is still very scarce. The survey showed the need to discuss the current state of knowledge. Our results suggest that, theoretically, NMES could be a promising method to attenuate the signs of aging; however, there are still no conclusive results regarding the clinical effectiveness of using NMES in the facial muscles since few studies relate NMES to facial rejuvenation. More studies are needed, with greater methodological rigor and low level of bias, using precise techniques in the evaluation and allowing to interpret with greater scientific commitment of the physiological mechanism of the muscular stimulus and its interrelation with the integumentary system, proving its effectiveness in the improvement of skin appearance.

Keywords | Neuromuscular Electrostimulation; Muscle Training; Skin Aging; Physical Therapy.

RESUMO | Embora seja um processo fisiológico natural, o envelhecimento é considerado degenerativo. Seus efeitos são evidentes na pele envelhecida, que apresenta redução de elasticidade, gordura e tônus muscular, assim como rugas, flacidez, alteração de contornos e sarcopenia. Tais mudanças podem gerar um estigma social e desconforto psicológico para o seu portador. Nesse contexto, objetivou-se avaliar a eficácia do uso da estimulação elétrica neuromuscular (EENM), uma técnica utilizada na Fisioterapia para o treinamento muscular, visando à atenuação dos sinais do envelhecimento facial. Para isso, foi realizado um levantamento de publicações indexadas nas plataformas MEDLINE (PubMed), CINAHL, Embase, PEDro, LILACS, ERIC, Scopus, Web of Science e Google Scholar e, a partir de critérios preestabelecidos, foram selecionadas duas publicações relevantes sobre o tema. A literatura científica sobre o uso da EENM na atenuação dos sinais do envelhecimento ainda é escassa. O levantamento revelou a necessidade de uma discussão a respeito do estado atual do conhecimento. Os resultados desta revisão sugerem que a EENM pode ser um método promissor de treinamento muscular quando aplicado à atenuação dos sinais de envelhecimento. Contudo, ainda há poucas evidências quanto à eficácia da EENM na musculatura da face, visto que poucos estudos relacionam a EENM ao rejuvenescimento facial. São necessários estudos com maior rigor metodológico,

Universidade Estadual de Campinas (Unicamp) – Campinas (SP), Brazil. E-mail: maconsulin@terra.com.br. ORCID-0000-0002-7458-4323
[2]Universidade Estadual de Campinas (Unicamp) – Campinas (SP), Brazil. E-mail: louise.ivasques@gmail.com. ORCID-0000-0003-3152-8468
[3]Universidade Estadual de Campinas (Unicamp) – Campinas (SP), Brazil. E-mail: gislaine.leonardi@fcf.unicamp.br. ORCID-0000-0002-7126-1326

Corresponding address: Gislaine Ricci Leonardi – Rua Cândido Portinari, 200 – Campinas (SP), Brazil – ZIP Code: 13083-871 – E-mail: gislaine.leonardi@fcf.unicamp.br – Financing source: CAPES (Code 0001) and FAPESP (2020/08516-0) – Conflict of interests: nothing to declare – Presentation: Apr. 19th, 2021 – Accepted for publication: Jan. 31st, 2023.

a fim de minimizar vieses, e utilização de técnicas precisas de avaliação, permitindo a elucidação do mecanismo fisiológico do estímulo muscular e sua inter-relação com o sistema tegumentar e possibilitando a comprovação da eficácia da EENM na melhoria da aparência da pele facial.
Descritores | Estimulação Elétrica Neuromuscular; Treinamento Muscular; Envelhecimento da Pele; Fisioterapia.

RESUMEN | El envejecimiento es un proceso fisiológico natural, aunque se considera un proceso degenerativo. Sus efectos son evidentes en la piel envejecida, que presenta disminución de la elasticidad, grasa y tono muscular, así como arrugas, flacidez, cambios de contorno y sarcopenia. Estos cambios pueden generar un estigma social y malestar psicológico para el portador. En ese contexto, el objetivo de este estudio fue evaluar la efectividad del uso de la estimulación eléctrica neuromuscular (NMES), una técnica utilizada en Fisioterapia de entrenamiento muscular para atenuar los signos del envejecimiento facial. Para ello, se realizó un relevamiento de las publicaciones indexadas en las plataformas MEDLINE (PubMed), CINAHL, Embase, PEDro, LILACS, ERIC, Scopus, Web of Science y Google Scholar, y, con base en criterios preestablecidos, se seleccionaron dos publicaciones relevantes sobre el tema. La literatura científica sobre el uso de NMES en la atenuación de los signos del envejecimiento es aún escasa. La búsqueda reveló la necesidad de una discusión sobre el estado actual del conocimiento. Los resultados de esta revisión sugieren que la NMES puede ser un método prometedor de entrenamiento muscular cuando se aplica para atenuar los signos del envejecimiento. Sin embargo, todavía hay poca evidencia con respecto a la efectividad de NMES en los músculos faciales, ya que pocos estudios relacionan NMES con el rejuvenecimiento facial. Son necesarios estudios con mayor rigor metodológico para minimizar sesgos y el uso de técnicas de evaluación precisas, que permitan dilucidar el mecanismo fisiológico del estímulo muscular y su interrelación con el sistema tegumentario y que permitan probar la eficacia de la NMES en la mejora del aspecto de la piel del rostro.
Palabras clave | Electroestimulación Neuromuscular; Entrenamiento Muscular; Envejecimiento de la Piel; Fisioterapia.

INTRODUCTION

Aging is a biologically programmed, gradual, complex, irreversible, structural weakening process that generates several changes in the body, increasing the risk of diseases and functionally modifying cells and tissues. Its effects usually appear from the third decade of life and progress over the years[1,2].

In the skin, aging is the combined result of intrinsic and extrinsic factors. Intrinsic factors are related to the natural physiological changes that occur due to genetically programmed aging, mostly hormone-regulated processes. Extrinsic factors, on the other hand, are related to one's lifestyle habits and environmental conditions that influence them. Some factors that can accelerate aging are consumption of alcohol; smoking; sleeping position; repetitive facial expressions; emotional stress; the action of gravity; and exposure to the sun's rays and pollution[1-4]. Moreover, skin function decays with age, which decreases the capacity for cell renewal and response to lesions and healing, in addition to reducing its barrier function, mechanical protection, DNA repair capacity, sensory perception, immune and vascular responsiveness, thermoregulation, and, finally, sweat, sebum, and vitamin D production[2,5].

Facial aging

The face is the body part that relates more directly with the outside world and due to the increase in life expectancy and the consequent growth in the older population, the concern with the loss of the characteristics that compose a "good appearance" has intensified, since many individuals react to the changes caused by aging with a deep feeling of grief, fear, and unacceptance, developing psychological disorders such as anxiety and depression[6].

Facial aging is the cumulative result of alterations in the skin, soft tissues, and osteocartilaginous framework over time. Its analysis can be based on the definition of skin as a structure supported by an underlying framework, a support system, and an external envelope[7]. The framework is the bone skeleton and, among the support structures, we can mention the nasal and auricular cartilages and the inferior tarsal plates, which, in turn, are complemented by the musculofascial system. The superficial musculoaponeurotic system (SMAS)[8] is directly connected to the outer layer of the skin through the fibrous interlobular septa of the fat, and the envelope is represented by the skin and the subcutaneous tissue[9].

Described in 1974 by Mitz and Peyronie, SMAS is a complex morphological unit that divides the subcutaneous tissue into two parts and consists of a fibromuscular layer that connects the mimetic muscles to each other and to the skin, being continuous with the platysma. SMAS extends from the malar region to the upper third of the face, joining the epicranial aponeurosis; for the lower third, it becomes part of the platysma, and laterally, in the middle third, it interdigitates to the parotid fascia (over the parotid gland). SMAS amplifies the contractions of the muscles in facial expressions, radiating them from the face to the skin[8-11]. For better visualization, Figure 1 shows the superficial face muscles and Figure 2 shows the description of the position of the SMAS.

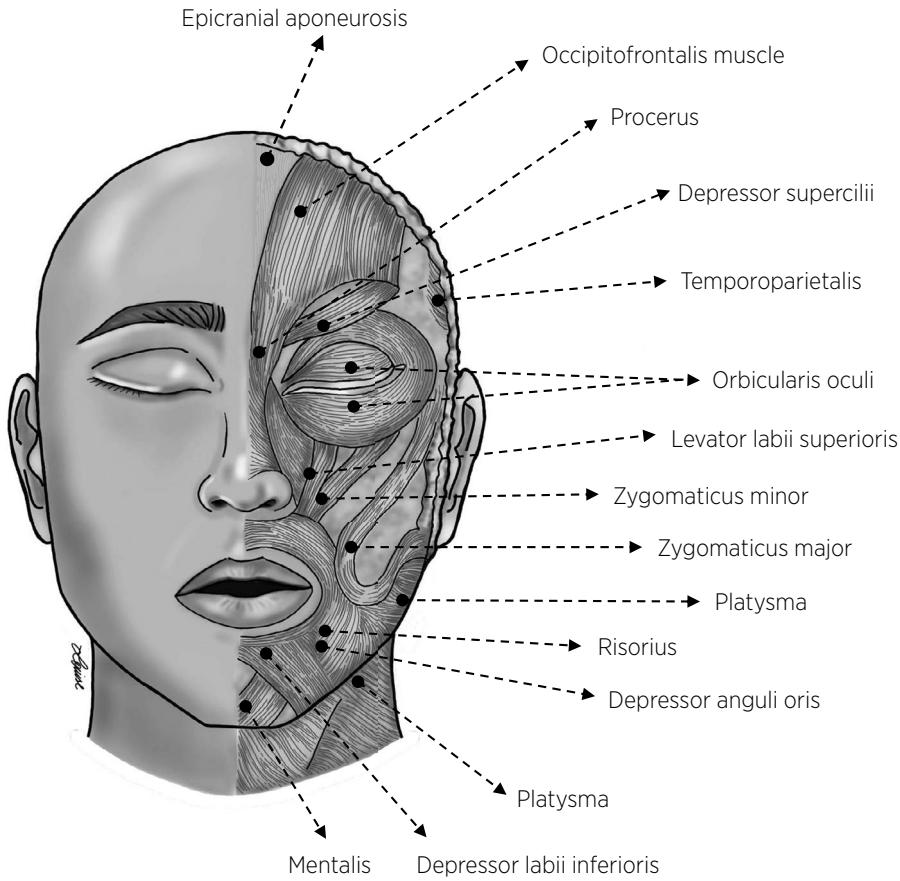

Figure 1. Midface: comparison of the outer layer with the superficial facial muscles

The arrows indicate the nomenclature of the muscles and/or regions.

The stability of the facial structure is also supported by specialized connective elements that ensure the position of specific structures of the framework, such as the medial and lateral canthal tendons, which stabilize and connect the tarsal to the various fibrous structures that interconnect the nasal cartilages[7]. The reduction of the intrinsic elasticity of the skin can attenuate the support system, which can be observed in eyelid ectropion, caused by the stretching of the lateral canthal tendon, and in nasal ptosis, provoked by the alteration of the fibrous support of its cartilages. The muscle-fibrous system also becomes attenuated, rearranging the skin into folds, known as wrinkles[12]. There are two types of wrinkles during life: gravitational wrinkles, resulting from atrophies associated with gravity, which usually lead to tissue ptosis; and dynamics, resulting from the movements generated in the facial expressions, which follow the traction lines of the skin[13,14].

Additionally, there is a reduction in facial fat, muscle tone, and elasticity, as well as to bone resorption associated with aging, leading to a loss of facial fullness and contour alteration associated with sagging and a relative excess of facial skin, causing a facial quadralization[15,16].

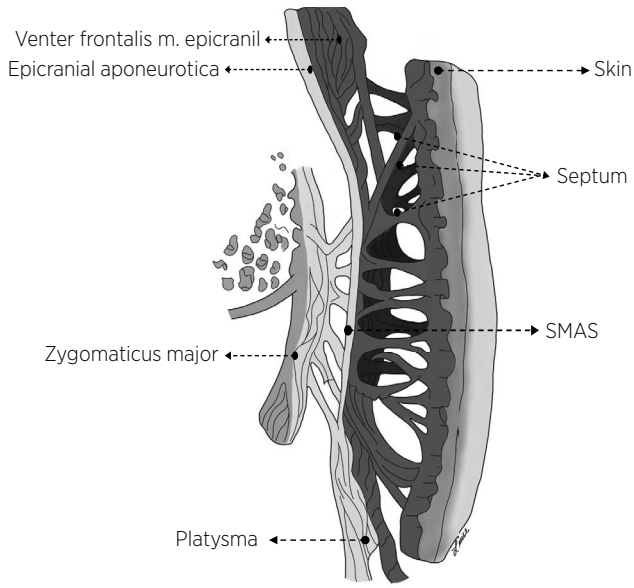

Figure 2. Representation of the superficial musculoaponeurotic system

SMAS: superficial musculoaponeurotic system. Arrows indicate the nomenclature of the muscles and/or regions.

Many facial rejuvenation procedures aim to restore the characteristics that confer volume to the face. These procedures consider the face as a whole and give importance to the maintenance of facial three-dimensionality, and not only to the treatment of wrinkles[16]. The reduction of skeletal muscle mass and strength (sarcopenia) is also part of aging; however, as skeletal muscle fibers retain considerable plasticity in old age, sarcopenia can be partially recovered according to functional demand[15].

However, the effects of aging on the skin can be postponed—preventing premature aging and improving quality of life—and mitigated via interventions and strategies to attenuate these effects[13]. Among non-invasive methodologies for attenuating the signs of skin aging, facial massage to relax and reduce muscle tension, facial exercises to improve muscle tone and skin firmness[17,18], and neuromuscular electrical stimulation (NMES) can be mentioned[19].

The applications of neuromuscular electrical stimulation

Luigi Galvani conducted the first study regarding muscle contraction by electric current in 1790[20]. Clinical therapy with neuromuscular electrical stimulation produces spasms (tetany) and consequent muscle contraction, being used for 'functional' purposes. Its conceptualization has been found in the literature since 1964[21], and the technique is based on the physiological principles of excitability of nerves and muscle fibers, showing positive results in different clinical treatments[21-25]. Today, NMES has been implemented in the aesthetic industry to strengthen facial muscles, especially in women, aiming to increase muscle mass and attenuate the aging appearance, supported by the use established in Physical Therapy regarding muscle strengthening in rehabilitation processes[15,19,26-28].

NMES can cause long-term changes in nerves and muscles due to the induction of electrical activity, which can determine the properties of muscle fibers, activating a sequence of signaling pathways that alter muscle gene expression[24]. The procedure consists of electrical stimulation of the muscles by specific electrodes adhered to the skin, close to the motor nerve—related to the musculature that is intended to be stimulated—, which leads to the contraction of the muscle by depolarization of the nerve fibers. This contraction positively influences muscle activation and is effective in strengthening muscles and preventing atrophy[29].

NMES is considered a method of muscle training for physical rehabilitation and strength training by inducing sequenced muscle contractions, supported by electrical stimulation. Continuous resistance training can promote muscle hypertrophy in all age groups[30]. Its advantage is that, besides being a versatile technique, NMES has no systemic effects, is not addictive, and has no undesirable side effects or complications[22]. NMES has been used clinically for different purposes, showing positive results for the treatment of muscle paralysis, reduction of edema, improvement of muscle strength, an increase of range of motion, tissue healing, treatment of muscle atrophy, and recovery of patients in intensive care units and/or affected by chronic cardiac and respiratory diseases[21,23-25].

Given the increased demand for aesthetic procedures and technologies capable of minimizing the effects caused by aging with a non-invasive intervention, and considering that health is not just about the absence of diseases, but about physical, psychological, and emotional well-being, this study is justified by the need to investigate the effectiveness of the NMES technique in attenuating the signs of aging on the facial

skin, because it is a well-known, cheap, easy to access intervention in Physical Therapy that has already been applied in aesthetic clinics in Brazil.

Objective

This study aims to investigate the efficacy of NMES in minimizing the effects of facial aging via an integrative literature review.

METHODOLOGY

To investigate the relationship between the use of NMES and facial rejuvenation, a survey of publications indexed on the databases MEDLINE (PubMed), CINAHL, Embase, PEDro, LILACS, ERIC, Scopus, Web of Science, and Google Scholar was conducted. In the selection of publications, the following keywords were used: "electrostimulation"; "neuromuscular electrostimulation"; "muscle stimulation"; or "NMES", and these were related to the following words: "facial"; and "face muscles," and then associated with the following purposes: "aging"; "rejuvenation"; or "aesthetic." The search was conducted in a single day and the studies available in free full text and that met the inclusion criteria were included in this review, which were clinical studies conducted in humans; those using NMES as an intervention; having the face as the target region; as a rejuvenation strategy or with aesthetic purpose. All studies that did not fit these criteria were excluded.

RESULTS

The search using the aforementioned keywords in the databases found a total of 24 studies and, of these, 22 were excluded (Figure 3).

The excluded articles used NMES but did not contemplate the objective of this study, investigating other purposes and regions of intervention. The recovery of body and facial mobility in cases of muscle paralysis, recovery of facial mobility after cosmetic procedures, dental and/or speech therapy procedures, and the use of facial muscles in expressing emotions were the most common topics, with very few studies addressing the use of NMES to attenuate the signs of facial aging.

Therefore, for this review, two studies in which facial rejuvenation was associated with NMES were selected; they were compared regarding design, procedures, and results obtained (Table 1), as well as in terms of quality, according to the PEDro scale (Table 2).

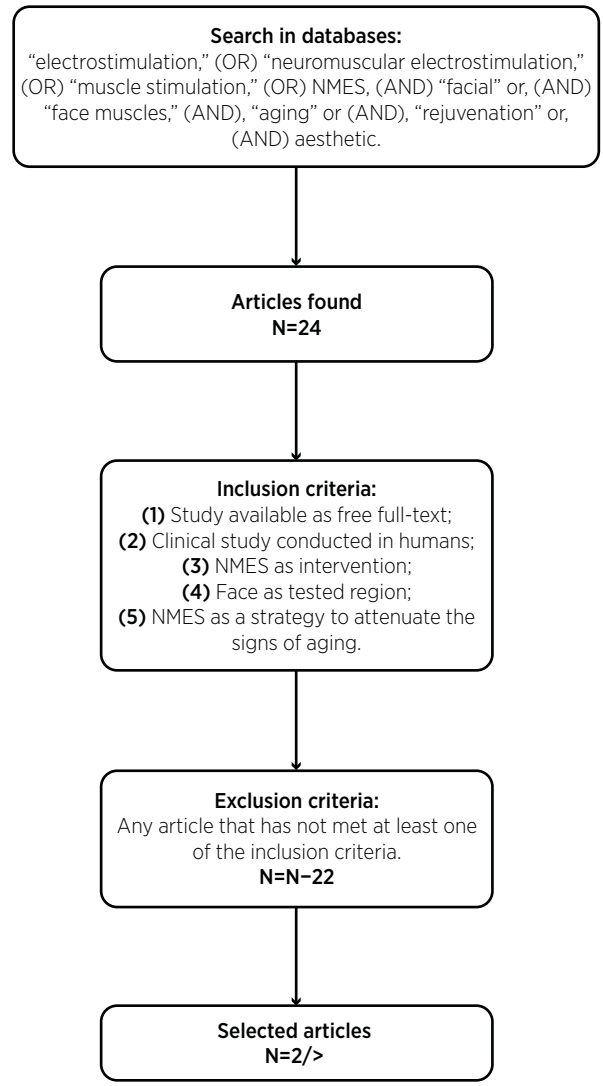

Figure 3. Strategy for selecting studies according to inclusion and exclusion criteria

NMES: neuromuscular electrical stimulation.

Table 1. Characterization of the included studies

Author/year	Category	Population	Procedures	Intervention and analysis instruments	Main results
Kavanagh et al., 2012[15]	Randomized, controlled, and partially blinded clinical study.	108 healthy women, aged 32 to 55 years, and with visible signs of facial aging; participants were randomly divided into intervention and control group.	The intervention group was trained in the use of the device, and the first treatment session was performed under supervision and the others were self-administered at home. A stimulation intensity that provided minimal visible muscle contraction was selected. The treatment was performed for 12 weeks with the NMES facial device, for 20min/day, five days per week. The control group received no intervention.	A 70Hz NMES facial device was used; psychometric surveys were applied for the determination of facial condition and appearance, including tone, firmness, support, brightness, and complexion; and ultrasonography of the zygomaticus major muscle was performed using a scanner with a linear transducer of 7.5–9.0MHz.	The intervention group showed thicker zygomaticus muscle major and subjective improvements in facial attributes, such as firmness, tone, and support, while the control group showed no improvements. The differences between the two groups were statistically significant at 6 and 12 weeks.
Nakaya et al., 2022[28]	Clinical study. There is no mention of all study criteria, such as whether or not a control group was present or whether the study was blinded.	10 healthy women, aged 21 to 22 years. There is no description of the inclusion and exclusion criteria.	The participants were trained in the use of the device and self-administered eight NMES procedures for 20min/day, two days per week.	The Pearl Face Esthe Sonic EX (ITO CO. LTD., Saitama, Japan) was used. The masseter and buccinator muscles were evaluated by magnetic resonance imaging using the ECHELON 1.5T scanner (Hitachi, Ltd., Ibaraki, Japan) before the first procedure and 2 or 3 days after the last day of intervention.	There was no significant difference in the volume of the right and left buccinator muscles before and after the use of the EMS facial device. There was a significant decrease in the volume of the right and left masseter muscles after the use of the EMS facial device, suggesting that the device can generate a beneficial effect on the masseter muscle in a short time.

EMS: electrical muscle stimulation.

Table 2. Evaluation of the quality of the studies according to the criteria established by the PEDro scale

Evaluative criteria	Kavanagh et al., 2012[15]	Nakaya et al., 2022[28]
1. Eligibility criteria were specified	Yes	Yes
2. Subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	Yes	No
3. Allocation was concealed	Yes	No
4.The groups were similar at baseline regarding the most important prognostic indicators	Yes	Yes
5. There was blinding of all subjects	No	No
6. There was blinding of therapists who administered therapy	No	No
7. There was blinding of all assessors who measured at least one key outcome	Yes	No
8. Measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	Yes	Yes
9. All subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"	Yes	Yes
10. The results of between-group statistical comparisons are reported for at least one key outcome	Yes	Yes
11. The study provides both point measures and measures of variability for at least one key outcome	Yes	Yes
Score*	8	5

*Score: the maximum possible score is 10, and the first criterion is worth no points. Only scores were assigned for criteria whose answer was "yes"; for all those who were not completely satisfied or in which the information was not mentioned, the answer "no" was assigned.

DISCUSSION

The scientific literature on the use of neuromuscular electrostimulation to mitigate the signs of facial aging is still scarce, showing the need for a discussion about the current state of knowledge.

The effectiveness of neuromuscular electrical stimulation in attenuating the signs of facial aging

Considering the concepts on facial aging, the changes that occur in the facial framework, and the applications of NMES in facial muscle training, some parameters are important for the elucidation of the real effectiveness of the technique for this purpose.

Similar to the practice of physical activity, especially in voluntary exercises, there is a relationship between the intensity of electrically induced muscle contraction and the neuromuscular benefits generated[31]. One of the main limiting factors of electrical stimulation could be the discomfort caused by the electrical current since the face has many sensory receptors and nerve endings. Investigating this, a study conducted by Safi[32] showed that healthy individuals were able to tolerate neuromuscular stimulation for muscle contraction, with an acceptable level of discomfort, at maximum intensities of approximately 60mA. Regarding parameters used in the selected studies, there was no consensus[32].

In the master's thesis conducted by Annala[33], in which two NMES devices were evaluated for the users' experience, the methodology used for parameter selection applied to devices that had their usability compared was not fully clarified. The Ageless Wonder equipment, with a 70Hz frequency, and the Lift Plus equipment at a 40Hz frequency were used. Before the experiments, the muscle stimulation tests and their programs were aligned regarding maximum tolerance intensity level. Each participant adjusted their own device to a tolerable intensity at which it was possible to obtain a visible muscle contraction[33]. Probably, as the main purpose was to evaluate the experience of electrical stimulation in relation to the functionality of the device and the satisfaction of the volunteer, the therapeutic intention was not the focus of the study.

Kavanagh et al.[15] used NMES in their experimental group for 12 weeks, five times per week, for 20 minutes. They used a 70Hz frequency, with a 100μs pulse width, and 35mA maximum intensity. Participants tolerated the procedure, with the appearance of a slight erythema at the site, which disappeared spontaneously. Note that this is a common occurrence in similar procedures of physical therapy clinical practice, although the eyelid fasciculation of a volunteer, in a sparse episode that was not repeated, was reported as a persistent adverse event[15].

Nakaya et al.[28] proposed a clinical study with 10 subjects who underwent magnetic resonance imaging evaluation of the masseter and buccinator muscles before and after intervention by NMES. These muscles were selected because they are involved in facial expression. The buccinator muscle showed no satisfactory response to the procedure, which was attributed to a failure in the contact of the probe with the region since the operator of the equipment was the user. On the other hand, the masseter muscle showed a favorable result of volume decrease, which was not considered as muscle loss, but rather a facial thinning[28].

To evaluate the quality of the studies, the PEDro scale was used as a parameter, available online and in several languages on the website: https://pedro.org.au/. The PEDro scale is based on the Delphi list, developed by Verhagen et al.[34] at the Department of Epidemiology of Maastricht University. Items 8 and 10 of the PEDro scale are not included in the Delphi list and were added later. The scale aims to evaluate the quality of clinical studies in Physical Therapy to facilitate the search for and application of effective physical therapy interventions based on scientific evidence.

The studies were evaluated according to the 11 established criteria and scored from 0 to 10 according to the satisfaction of the criteria. No score was given to criterion 1 or to the criteria whose answer was "no." Regarding the final score attributed to the studies, those who obtained scores 6–10 were considered good quality; 4–5, medium quality; and 0–3, poor quality. Thus, the study by Kavanagh et al. was considered good, and that of Nakaya et al. was medium quality.

Both studies were biased since they had unsatisfied and/or partially satisfied answers. Some of the problems were:

- Participants conducted the NMES procedure, which may generate differences in the way the device is used, difficulty locating the target muscles, and lack of control and supervision in performing the procedure at home;

- The study conducted by Kavanagh et al.[15] does not mention name nor the brand of the devices. In turn, Nakaya et al.[28] does not mention all the information about the study, such as criteria for selecting participants, randomization, presence or absence of a control group, and whether the study was blinded in any instance, either participants or researchers who performed the analyses.

The studies also differ from each other regarding the methodology of analysis of the stimulated muscles: Kavanagh et al.[15] used ultrasonography and Nakaya et al.[28] magnetic resonance imaging. Furthermore, the study by Kavanagh et al.[15] performed psychometric surveys for the determination of facial condition and appearance, including tone, firmness, support, brightness, and complexion, measures considered important for aesthetic studies, and which were not evaluated in the study by Nakaya et al.[28].

The mechanism of action of NMES for facial rejuvenation, although used by aesthetic physical therapy, lacks studies on the facial rejuvenation from the gain of trophism of facial muscles; however, sarcopenia can be attenuated with muscle training, both via voluntary exercises and by muscle electrostimulation[26,35].

It is suggested that NMES for facial rejuvenation could act in the optimization of local blood circulation, in the activation of collagen and elastin synthesizing fibroblasts, and in the toning of facial muscles, which, due to the action of gravity, become flaccid, giving the impression of an aging face[24].

Other associations could be suggested, since it is common knowledge that aging is associated with a deterioration of the skin, observable both in the functional decay as a barrier and in the increase of susceptibility to diseases. It is hypothesized that mitochondrial weakness is responsible for altering the metabolism and homeostasis of the skin, promoting the signs of aging. Muscle contraction can induce the secretion of Interleukin-15 and function as a regulator of mitochondrial function, attenuating skin aging[36].

Abundant, skeletal muscle cells are metabolically active and known to signal their energy demands to other organs by actively secreting myokines, which are excreted in response to muscle contraction or strength training. Myokines are produced predominantly in skeletal muscle and released into the skin by blood vessels. In sarcopenia, in which there is a decrease in muscle mass, there is also a decrease in some myokines in the blood. Muscle, then, can become a fascinating "key anti-aging factor," modulating senescence throughout the body, including skin[27].

The application of NMES in the face of healthy individuals has a theoretical basis, based on its use in Physical Therapy practices to increase muscle strength and muscle thickness with atrophy—either by hypertrophy of the muscle fiber or by shortening the muscle resting length[20]. However, both the efficacy of NMES and its mechanism of action in facial muscles for attenuation of signs of aging still need to be studied and elucidated.

We suggest future studies to be designed with greater scientific rigor, control, and standardization of investigation parameters so that there is a possibility not only to compare methodologies but also to reproduce therapeutic protocols. Moreover, we consider that the most convenient way to use NMES is by small portable units, whose resources are modifiable, allowing professionals to define parameters and create customized programs according to the desired objective[20,33].

CONCLUSION

Neuromuscular electrical stimulation is a promising non-invasive procedure for attenuating the signs of facial aging. However, the literature lacks evidence on the subject, making clear the need to conduct studies with greater methodological rigor, to minimize the level of biases, and to use precise evaluation techniques that allow for the elucidation of the physiological mechanism of muscle stimulation and its interrelationship with the integumentary system, allowing to prove the effectiveness of NMES in improving the appearance of facial skin.

ACKNOWLEDGMENTS

To the Coordination for the Improvement of Higher Education Personnel (CAPES) – code 0001 – and the São Paulo Research Foundation (FAPESP) – Process No. 2020/08516-0.

REFERENCES

1. Fibrich BD, Lall N. Fighting the inevitable: skin aging and plants. In: Lall N, editor. Medicinal plants for holistic health and

well-being. London: Academic Press; 2018. p. 77-115. doi: 10.1016/B978-0-12-812475-8.00003-2.

2. Niamtu J 3rd. The aging face. In: Niamtu J 3rd. The art and science of facelift surgery: a video atlas. Virginia: Elsevier Health Sciences; 2019. p. 6-20.
3. Shah MG, Maibach HI. Estrogen and skin: an overview. Am J Clin Dermatol. 2001;2(3):143-50. doi: 10.2165/00128071-200102030-00003.
4. Sajna KV, Gottumukkala LD, Sukumaran RK, Pandey A. White biotechnology in cosmetics. In: Pandey A, Höfer R, Taherzadeh M, Nampoothiri KM, Larroche C, editors. Industrial biorefineries & white biotechnology. Amsterdam: Elsevier; 2015. p. 607-52. doi: 10.1016/B978-0-444-63453-5.00020-3.
5. Yaar M. Clinical and histological features of intrinsic versus extrinsic skin aging. In: Gilchrest BA, Krutmann J, editors. Skin aging. Berlin: Springer; 2006. p. 9-21. doi: 10.1007/3-540-32953-6_2.
6. Takacs AP, Valdrighi V, Assencio-Ferreira VJ. Fonoaudiologia e estética: unidas a favor da beleza facial. Rev CEFAC. 2002;4(2):111-6.
7. Mélega JM, Reiff ABM. Introdução à cirurgia plástica. In: Mélega JM. Cirurgia plástica: fundamentos e arte: princípios gerais. Rio de Janeiro: Medsi; 2002. p. 3-8.
8. Granja ST. El SMAS descripción anatómica y estudio de la extensión del mismo en la cabeza. Revista Argentina Anatomía Online. 2015;6(4):191-5.
9. Montedonio J, Queiroz Filho W, Pousa CET, Paixão MP, Almeida AEF. Fundamentos da ritidoplastia. Surg Cosmet Dermatol. 2010;2(4):305-14.
10. Frazão Y, Manzi SB. Effectiveness of speech therapy intervention for mitigating facial aging. Rev CEFAC. 2012;14(4):755-62. doi: 10.1590/S1516-18462010005000124.
11. Kadunc BV, Palermo E, Addor FAS, Metsavaht LD, Rabello L, Bezerra SMC. Tratado de cirurgia dermatológica, cosmiatria e laser da Sociedade Brasileira de Dermatologia. Rio de Janeiro: Elsevier; 2012.
12. Farkas JP, Pessa JE, Hubbard B, Rohrich RJ. The science and theory behind facial aging. Plast Reconstr Surg Glob Open. 2013:1(1):e8-15. doi: 10.1097/GOX.0b013e31828ed1da.
13. Cipriani E, Bernardi S, Continenza MA. Wrinkles: origins and treatments. Advances in Cosmetics and Dermatology. 2016;2(1):1-7.
14. Lemperle G, Holmes RE, Cohen SR, Lemperle SM. A classification of facial wrinkles. Plast Reconstr Surg. 2001;108(6):1735-50; discussion 1751-2.
15. Kavanagh S, Newell JN, Hennessy M, Sadick N. Use of a neuromuscular electrical stimulation device for facial muscle toning: a randomized, controlled trial. J Cosmet Dermatol. 2012;11(4):261-6. doi: 10.1111/jocd.12007.
16. Coimbra DD, Uribe NC, Oliveira BS. "Quadralização facial" no processo do envelhecimento. Surg Cosmet Dermatol. 2014;6(1):65-71.
17. Van Borsel J, De Vos MC, Bastiaansen K, Welvaert J, Lambert J. The effectiveness of facial exercises for facial rejuvenation: a systematic review. Aesthet Surg J. 2014;34(1):22-7. doi: 10.1177/1090820X13514583.
18. Alam M, Walter AJ, Geisler A, Roongpisuthipong W, Sikorski G, Tung R, et al. Association of facial exercise with the appearance of aging. JAMA Dermatol. 2018;154(3):365-7. doi: 10.1001/jamadermatol.2017.5142.
19. Piccolino M. Animal electricity and the birth of electrophysiology: the legacy of Luigi Galvani. Brain Res Bull. 1998;46(5):381-407. doi: 10.1016/S0361-9230(98)00026-4.
20. Doucet BM, Lam A, Griffin L. Neuromuscular electrical stimulation for skeletal muscle function. Yale J Biol Med. 2012;85(2):201-15.
21. Guimarães BTL, Furkim AM, Silva RG. Eletroestimulação neuromuscular na reabilitação da disfagia orofaríngea. Rev Soc Bras Fonoaudiol. 2010;15(4):615-21. doi: 10.1590/s1516-80342010000400024.
22. Gondin J, Brocca L, Bellinzona E, D'Antona G, Maffiuletti NA, Miotti D, et al. Neuromuscular electrical stimulation training induces atypical adaptations of the human skeletal muscle phenotype: a functional and proteomic analysis. J Appl Physiol (1985). 2011;110(2):433-50. doi: 10.1152/japplphysiol.00914.2010.
23. Vrbová G, Hudlicka O, Centofanti KS. Electrical stimulation as a therapeutic tool to restore motor function. In: Vrbová G, Hudlicka O, Centofanti KS. Application of muscle/nerve stimulation in health and disease. Dordrecht: Springer; 2008. p. 55-67.
24. Griffin M, Nicolaides AN, Bond D, Geroulakos G, Kalodiki E. The efficacy of a new stimulation technology to increase venous flow and prevent venous stasis. Eur J Vasc Endovasc Surg. 2010;40(6):766-71. doi: 10.1016/j.ejvs.2010.06.019.
25. Saniee F, Shirazi HRG, Kalantari KK, Yazdanpanah P, Soltani AR, Dabiri N, et al. Consider of micro-current's effect to variation of facial wrinkle trend, randomized clinical trial study. Life Science Journal. 2012;9(3):1184-9.
26. Roubenoff R, Hughes VA. Sarcopenia: current concepts. J Gerontol A Biol Sci Med Sci. 2000;55(12):716-24. doi: 10.1093/gerona/55.12.M716.
27. Nishikori S, Sassa S, Suzuki T, Takeuchi H. Beauty and muscle – the secret effect on the skin. Proceedings of the 30th Congress IFSCC; 2018; Munich. New York: IFSCC; 2018.
28. Nakaya K, Muto H, Matsuura K, Sudo S, Yamanaka A. The effects of electrical muscle stimulation on facial muscles: volume change of facial muscles measured with magnetic resonance imaging. Journal of JART [Internet]. 2022 [cited 2023 Mar 23];69(831):40-7. Available from: https://3medgroup.com/wp-content/uploads/2022/09/EMS.pdf
29. Oh DH, Park JS, Kim WJ. Effect of neuromuscular electrical stimulation on lip strength and closure function in patients with dysphagia after stroke. J Phys Ther Sci. 2017;29(11):1974-5. doi: 10.1589/jpts.29.1974.
30. Tsukahara K, Tamatsu Y, Sugawara Y, Shimada K. Relationship between the depth of facial wrinkles and the density of the retinacula cutis. Arch Dermatol. 2012;148(1):39-46. doi: 10.1001/archdermatol.2011.727.
31. Liebano RE, Alves LM. Comparação do índice de desconforto sensorial durante a estimulação elétrica neuromuscular com correntes excitomotoras de baixa e média frequência em mulheres saudáveis. Rev Bras Med Esporte. 2009;15(1):50-3. doi: 10.1590/S1517-86922009000100011.

32. Safi M. Assessing discomfort levels during facial neuromuscular electrical stimulation using discomfort level scale: a preliminary study. Indian J Otolaryngol Head Neck Surg. 2022;74(Suppl 3):5275-9. doi: 10.1007/s12070-020-02173-5.

33. Annala T. Electrical stimulation of facial muscles: user experience of two facial muscle stimulation devices [master's thesis]. Tampere: University of Tampere; 2017.

34. Verhagen AP, de Vet HC, de Bie RA, Kessels AG, Boers M, Bouter LM, et al. The Delphi list: a criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. J Clin Epidemiol. 1998;51(12):1235-41. doi: 10.1016/s0895-4356(98)00131-0.

35. Abe T, Loenneke JP. The influence of facial muscle training on the facial soft tissue profile: a brief review. Cosmetics. 2019;6(3):50. doi: 10.3390/cosmetics6030050.

36. Crane JD, MacNeil LG, Lally JS, Ford RJ, Bujak AL, Brar IK, et al. Exercise-stimulated interleukin-15 is controlled by AMPK and regulates skin metabolism and aging. Aging Cell. 2015;14(4):625-34. doi: 10.1111/acel.12341.