Eur J Transl Myol 33 (4) 11630, 2023 doi: 10.4081/ejtm.2023.11630

# Efficacy of adding selective electrical muscle stimulation to usual physical therapy for Bell's palsy: immediate and six-month outcomes

Antonio Di Pietro (1), Michelle Cameron (2,3), Vilma Campana (4), Laura Leyes (5), Jessica Andrea Isabel Zalazar Cinat (5), Carly Lochala (6,7), Christopher Z Johnson (8), Andrea Hildebrand (9,10), Myriam Loyo (8)

*(1) Department of Biophysics, Universidad Siglo 21, Córdoba, Argentina; (2) Department of Neurology, Oregon Health & Science University, Portland, OR, USA; (3) VA Portland Health Care System; (4) Department of Biomedical Physics, Facultad de Ciencias Médicas, Universidad Nacional de Córdoba, Córdoba, Argentina; (5) Department of Kinesiology and Physical Therapy, Universidad Nacional del Nordeste, Corrientes, Argentina; (6) Department of Rehabilitation, Oregon Health & Science University, Portland, OR, USA; (7) Division of Biokinesiology & Physical Therapy, University of Southern California, USA; (8) Department of Otolaryngology – Head and Neck Surgery, Oregon Health & Science University, Portland, OR, USA; (9) Biostatistics and Design Program, Oregon Health & Science University, Portland, OR, USA; (10) Portland State University School of Public Health, Portland, OR, USA.*



***Abstract***

Bell's palsy is the most common cause of facial paralysis, affecting one in every 60 people in their lifetime. Transcutaneously applied selective electrical muscle stimulation could potentially accelerate recovery from Bell's palsy but this intervention remains controversial. Studies have shown benefit, but concerns for lack of efficacy and potential for worsening synkinesis remain. We performed a prospective controlled trial comparing outcomes at initial recovery and six months later with selective electrical muscle stimulation and usual physical therapy versus usual physical therapy alone in adults with acute Bell's palsy. Outcomes were facial function assessed with the House Brackman and eFACE scales. Outcomes were evaluated at discharge and six months after discharge. Discharge occurred when participants were judged to be fully recovered by their treating therapist and supervisor. 38 adults participated in the study. Participants in the electrical stimulation group achieved maximal recovery twice as fast as the control group (2.5 weeks versus 5.2 weeks) with no significant differences in facial function or synkinesis between groups at any time point. This study is the first human trial of electrical stimulation in Bell's palsy to follow patients 6 months from recovery and supports that selective electrical muscle stimulation accelerates recovery and does not increase synkinesis.

**Key Words**: Bell's palsy; facial paralysis; synkinesis; long pulse electrical muscle stimulation; clinical trial.

*Eur J Transl Myol 33 (4) 11630, 2023 doi: 10.4081/ejtm.2023.11630*

Bell's palsy, an idiopathic facial nerve palsy, is the most common cause of facial paralysis. One in 60 people experience Bell's palsy in their lifetime.[1,2] The functional and psychological consequences of facial paralysis are substantial.

Affected patients cannot close their eyes for protection, and cannot control their lips to speak, smile, and retain food and saliva in their mouth. In Bell's palsy, the degree of paralysis ranges from mild weakness to complete paralysis. Onset of paralysis is relatively quick, reaching maximum severity within 72 hours from onset, and resolution is slow, taking from a few weeks to up to 6 months.[3] Most people recover full facial muscle strength. However 29% of patients develop synkinesis which involves involuntary ipsilateral facial muscle contractions, facial muscle spasms, and unintentional facial movement that occurs simultaneously with intentional movement.[4,5]

Synkinesis also has substantial consequences including inability to smile, difficulty eating and speaking, difficulty with vision, and distorted facial appearance. Synkinesis is thought to be caused by aberrant muscle re-innervation by the facial nerve.[6] Synkinesis typically

develops 6 months after onset of flaccid paralysis.[7] Transcutaneously applied selective electrical stimulation can produce muscle contractions in paralyzed denervated muscles, including facial muscles affected by Bell's palsy.

Such selective electrical muscle stimulation could potentially shorten the duration of paralysis and reduce long-term sequelae of Bell's palsy by preventing muscle atrophy and improving selectivity of re-innervation. While electrical stimulation for recovery after musculoskeletal and central nervous system injury has been widely studied and shown to accelerate recovery,[8-12] the effectiveness of electrical stimulation for Bell's palsy remains controversial.[13] Expert researchers and practicing clinicians are divided in their opinions on the use of electrical stimulation in this context; some assert it improves recovery, while other are concerned about adverse effects, particularly potentially increasing the risk for or severity of synkinesis.[13-15]

Previously published human clinical trials of electrical stimulation for Bell's palsy have substantial limitations.[16-23]

The trials are not controlled (only one is randomized),[20] do not account for predictors of prognosis, use insensitive outcome measures, and do not follow patients for long enough to evaluate for synkinesis.

For example, complete paralysis is a significant predictor of sequelae, with 61% of patients with complete paralysis developing synkinesis.[4]

In the previously published clinical trials, the baseline degree of paralysis is not clearly reported. The most commonly used outcome measure has been the House Brackmann (HB) scale, which gives a global score for facial function ranging from I to VI. This scale has low inter-rater reliability and lacks precision in capturing differences in facial function.[24]

Blinding to group allocation is uncommon in prior studies. We found only one study with blinded evaluators).[20] Furthermore, although synkinesis takes up to 6 months from initial recovery to develop, prior clinical trials only followed participants for up to 3 months. Additionally, the electrical stimulation parameters used in prior clinical trials for Bell's palsy have varied. Most used sufficient intensity to produce muscle contraction (one used subsensory stimulation), [19] which is intended to prevent or delay muscle atrophy.[25,26] Both monophasic and biphasic pulsed currents have been used.

Monophasic electrical currents may be most effective as they have been shown to promote tissue healing which could be beneficial in Bell's palsy.[27-30]

To more fully elucidate the impacts of selective electrical muscle stimulation in patients with Bell's palsy, we performed a prospective controlled trial comparing selective electrical muscle stimulation, using a monophasic pulsed exponential waveform together with usual physical therapy versus usual physical therapy alone in the treatment of adults with acute Bell's palsy. The eFACE scale, a sensitive validated clinician-graded scale of facial paralysis with high interrater and intrarater reliability, with scores for static, dynamic, and synkinesis facial function, was used as the primary outcome measure.[31,32] Evaluators were blinded to group allocation by using high quality video recordings of participants for the eFACE grading. Participants were followed for 6 months beyond their initial recovery to assess for eventual development of synkinesis.

## Materials and Methods

### *Subjects and design*

This was a single-blind, alternating allocation (active or control), controlled trial comparing usual physical therapy plus selective electrical muscle stimulation (active) to usual physical therapy (control) for treatment of acute Bell's palsy in adults. Evaluators were blinded to the intervention, while research subjects and treating therapists were aware of the treatment used. The study took place between February 2017 and December 2018 at the Kinesiology Department at the National University of the Northeast (Universidad Nacional del Nordeste (UNNE) in Argentina.

Inclusion criteria were diagnosis of acute (up to one month from onset of paralysis), incomplete, Bell's palsy. Potential participants were excluded if they had other causes of facial paralysis, or had hypertension, diabetes, or complete facial paralysis given the potential impact on outcome. Patients who had received prior facial physical therapy or muscle stimulation were also excluded. The diagnoses of Bell's palsy and comorbid conditions were made by the referring physician. Referrals came from primary care, neurology, and emergency physicians. Participants did not receive oral corticosteroids or antivirals.

The study was approved by the ethics committee of UNNE and all participants provided informed consent. After providing consent, participants were allocated alternately to the active or control condition. Data were captured from the first 20 participants who completed each allocation. The trial was registered at ISRCTN registry 14974687.

### *Usual physical therapy (control condition)*

Usual physical therapy included neuromuscular reeducation (NMR) in front of a mirror and massage therapy. NMR focused on creating symmetric facial expressions by activating the affected side and avoiding over-activation of the unaffected side[33-35]. Participants performed the following 11 facial expressions: raise the eyebrows, frown, blink, close the eyes tightly, contract the nose, kiss, blow air, Mona Lisa smile (without teeth), large smile (with teeth), pout, and inflate the cheeks. Depending on the degree of dysfunction, the therapist aided the movement or helped suppress a movement. Participants performed 5 sets of movements, each repeated 5 times (approximate duration 12 minutes). Massage therapy was provided extending from the

Eur J Transl Myol 33 (4) 11630, 2023 doi: 10.4081/ejtm.2023.11630

***Table 1.*** *Clinicodemographic characteristics of the analyzed study participants in the control and selective electric stimulation group.*

| | All | Control group | Selective electric muscle stimulation group |
|---|---|---|---|
| Number of participants | 38 | 18 | 20 |
| Age, years: mean (sd) | 38.0 (16.4) | 36.8(15.6) | 39.2 (16.8) |
| Sex, female: n (%) | 17 (44.7) | 10 (55.6) | 7 (35.0) |
| Side of paralysis, right: n (%) | 19 (50) | 8 (44.4) | 11 (55.0) |
| Days since onset of paralysis: mean (sd) | 8.2 (6.4) | 9.2 (8.2) | 6.9 (3.8) |
| House-Brackman at presentation: median (IQR) | 3.9 (1.0) | 4 (3-5) | 3.5 (3-4) |

*Note: SD= standard deviation,*
*IQR= interquartile range (25$^{th}$ and 75$^{th}$ percentile)*

scapula and neck to the scalp and face. This usual physical therapy intervention lasted 15 to 20 minutes.

***Selective electrical muscle stimulation (added to usual physical therapy for the active condition)***

The active selective electrical muscle stimulation group received electrical stimulation in addition to the above-described usual physical therapy. Electrical stimulation was applied transcutaneously with an indirect digital technique with the positive electrode on the ipsilateral neck of the patient and the negative electrode on the dominant forearm of the treating physical therapist. Electrical contact of these electrodes was achieved with wet cotton gauze. Stimulation was then provided by the therapist's fingers being applied to the treatment locations on the patient's face, with gel for electrical contact between the fingers and the skin of the patient's face (Figure 1).

Stimulation was applied on the affected side to the following muscles: frontalis, orbicularis oculi, nasalis, zygomatic major, orbicularis oris, and mentalis. The current had a monophasic exponentially rising pulsed waveform, with pulse width of 30 to 200ms, no interpulse interval, and therefor a resulting frequency of 5 to 33.3 pulses per second. The pulse width and current amplitude were adjusted by the treating therapist to optimize comfort and muscle contraction strength and selectivity (Neuromatic 700, Meditea®, Buenos Aires, Argentina). Five maximal strength, patient tolerated, contractions per muscle group were performed[36]. The selective electrical muscle stimulation added approximately an additional 20 minutes to the appointment length. All participants were treated daily, 5 days a week (Monday through Friday), until discharge which was when they were judged to be fully recovered by their treating therapist. The physician supervising the physical therapists clinically evaluated recovery when the treating therapist judged the participant to be fully recovered. The supervising physician was blinded to treatment allocation and

***Fig 1.*** *Photo of the set up for selective electrical muscle stimulation. Stimulation was applied transcutaneously with a digital technique where the positive electrode was placed on the ipsilateral neck of the patient and the negative electrode was placed on the dominant forearm of the treating physical therapist. Stimulation was provided by the therapist's fingers being applied to treatment locations on the patient's face. The photo shows a co-author volunteering to demonstrate the setup (MC).*

***Table 2.*** *Static, dynamic, and synkinesis eFACE scores at enrollment, discharge, and 6-month follow up for the control and selective electric stimulation group. There was no difference in the scores between the two groups..*

| | | Control group | Selective electric muscle stimulation group | p-value* |
|---|---|---|---|---|
| Static [Mean (SD)] | Enrollment | 75.2 (18.2) | 80.5 (14.1) | 0.12 |
| | Discharge | 90.5 (7.8) | 93.0 (2.9) | 0.34 |
| | 6-month follow up | 92.4 (4.7) | 95.1 (3.5) | 0.66 |
| Dynamic [Mean (SD)] | Enrollment | 43.8 (18.4) | 39.2 (19.6) | 0.25 |
| | Discharge | 83.2 (17.4) | 89.8 (7.3) | 0.12 |
| | 6-month follow up | 88.6 (12.5) | 94.7 (3.9) | 0.06 |
| Synkinesis [Mean (SD)] | Enrollment | 100 (0) | 100 (0) | 0.89 |
| | Discharge | 97.3 (4.1) | 99.1 (2.5) | 0.30 |
| | 6-month follow up | 94.8 (7.9) | 98.4 (2.3) | 0.92 |

*Note: SD= standard deviation, * p-value obtained from mixed effects linear regression model. See supplementary materials.*

affected side of the face. If recovery was confirmed treatment was discontinued and the patient was discharged from physical therapy. If the patient was found to have residual weakness, physical therapy was continued until maximal recovery.

### *Assessments and outcomes*

Baseline characteristics including age, gender, side of paralysis, and days from onset of paralysis to initiation of therapy were recorded on enrollment. Videos of participants performing the 11 facial expressions performed during physical therapy were recorded at enrollment, discharge from physical therapy, and at a follow-up visit 6 months after discharge from physical therapy. The video-recorded facial movements were rated by two independent, blinded reviewers using two scales, the House Brackman (HB) scale and the eFACE scale. HB scores each expression from I to VI, where I is normal and VI is complete paralysis.[24] eFACE rates on a scale from 0 to 100, where 100 is normal and lower scores indicated greater dysfunction. eFACE also provides subscores for static, dynamic and synkinesis on the same scale.[37]

### *Statistical analysis*

Results from participants who adhered to the entire assigned treatment protocol were analyzed to examine for differences between groups in improvements in HB and eFACE scores and in time to maximum improvement. Mixed effects linear regression models were built to characterize differences between groups in trajectory over time for static, dynamic, and synkinesis eFACE scores. Models included fixed effects for group assignment, days since onset of paralysis at enrollment, evaluation (enrollment, discharge, or 6-months post-discharge), weeks elapsed at each outcome evaluation, and a random participant effect to account for within-participant correlations over repeated measurements. The difference between groups at each evaluation was characterized by the interaction between group and evaluation. (See Supplementary Materials: Regression Model Specification; Regression Model Output; Table S2; Table S3).

To test for between-group difference in time to recovery, a linear regression model, with adjustment for days from onset of paralysis, was used to compare the total number of treatment sessions between groups. Statistical analyses were conducted using Stata version 15.1 (StataCorp LLC, College Station, TX)[38] and R version 4.0.3 (R Core Team, Vienna, AT) .[39] Visualizations were created in R using the ggplot2 package.[40]

## Results

There were initially 40 participants in the study, 20 in each group. Data from 38 (18 in the control group and 20 in the active experimental group) were analyzed. Data from 2 participants in the control group were excluded because, upon review, they did not meet inclusion criteria (one did not have Bell's palsy as the cause of their facial paralysis and the other one had complete rather than incomplete paralysis). The characteristics of the 38 participants are shown in Table 1.

The final HB score at discharge from treatment was 1 (IQR 1,2) for the control group and 1 (IQR 1,1) for the active group. The mean static, dynamic and synkinesis scores on the eFACE scale at enrollment, discharge, and 6 month follow up from discharge are shown in Table 2.

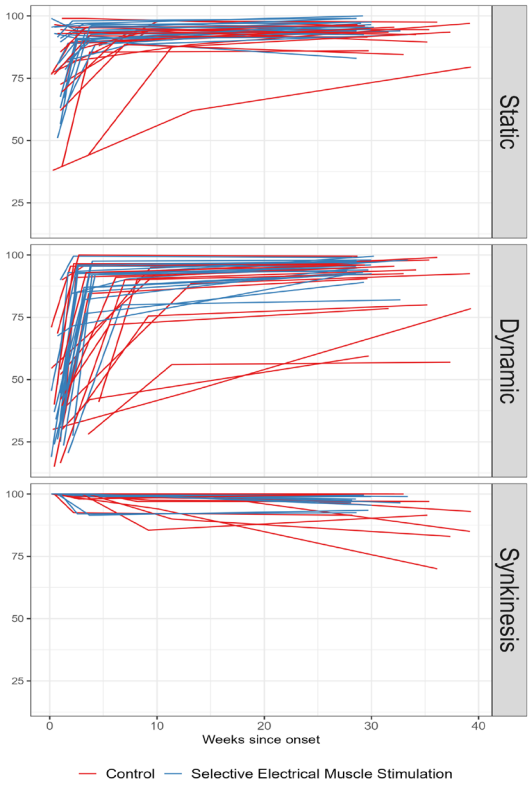


***Fig 2**. Dynamic, static, and synkinesis mean eFACE scores at enrollment, discharge, and 6-month follow up for the active selective electric stimulation group (in blue) and the control group (in red). There was not a statistically significant difference in mean scores between groups at any evaluation time point. However, the active selective electric stimulation group scores were consistently better and the inflection point of the line which reflects the time of discharge, is earlier in the active group.*

After adjusting for time to evaluation, there were no statistically significant differences between groups in the static, dynamic, or synkinesis eFACE scores at any evaluation. Figure 1 shows individual static, dynamic and synkinesis eFACE scores over time.

Time to maximum improvement from flaccid paralysis was estimated from the time from starting to ending the intervention as the mean time from onset of symptoms to initiation of therapy was not different between groups and participants were discharged from the intervention when judged to be maximally recovered. Mean time from starting to ending the intervention was 5.2 weeks (SD 3.6) for the control group and 2.5 weeks (SD 1.2) for the active group. The control group took 2.7 weeks longer than the selective electric stimulation group to reach maximal improvement of flaccid paralysis. This difference was statistically significant by a two-tailed t test ($t(20.1) = 3.01$, $p=0.01$).

## Discussion

This controlled trial supports that adding selective electrical muscle stimulation to the usual physical therapy intervention of exercise and massage in acute Bell's palsy is associated with significantly accelerated recovery from flaccid paralysis, and with a similar final outcome with regards to static facial expression, dynamic facial movement, and synkinesis.

Shortening the duration of Bell's palsy associated facial paralysis benefits patients by shortening the time they have poor eye closure and thus risk of eye damage, and by reducing the duration of the nutritional and psychosocial impacts of impaired eating, drinking, speech and non-verbal communication through facial expression. Knowing that this intervention does not increase the risk of developing synkinesis also increases its clinical value and appeal.

In our study, recovery from facial paralysis was achieved in approximately half the time in participants treated with selective electrical muscle stimulation plus usual physical therapy compared to participants treated with usual physical therapy alone (2.5 weeks versus 5.2 weeks). Upon recovery, static and dynamic facial function was similar with or without selective electrical muscle stimulation. Although the selective electrical muscle stimulation group had slightly better facial function scores, the difference was not statistically significant and the clinical relevance of this small difference is not known as the minimal clinically important difference for the eFACE scale has not been determined. Consistent with our findings, earlier, but similar, final recovery with electrical muscle stimulation has also been shown in the rehabilitation of other conditions associated with muscle weakness, such as after anterior cruciate ligament reconstruction.[41-43]

One of the main reasons clinicians avoid using electrical stimulation in patients with Bell's palsy is fear of increasing the risk for synkinesis.[13] However, reassuringly, we found no difference in synkinesis between groups, even 6 months after recovery from flaccid paralysis. Similarly, Puls *et al*. found no worsening in synkinesis one year after electrical stimulation in a small group of patients with facial nerve weakness after benign tumor removal.[44]

This study has a number of strengths. The interventions were standardized and both the physical therapy and selective electrical muscle stimulation were provided by experienced physical therapists. The protocol for electrical stimulation, with a long pulse duration and long exponential rise, was ideal for denervated muscle.[45] The outcomes were based on recordings of facial expressions to allow for independent assessment, and were measured at baseline, on maximal recovery from paralysis, and 6 months later, to capture both recovery of facial strength and onset of synkinesis, and the outcome evaluators were blinded to treatment allocation. In addition to the HB scale, the eFACE scale provided more precise and complete assessment of the participants' facial function.

This study also had limitations. Certain aspects of the study, including alternating rather than random group allocation, differences in the duration of the control and active treatment sessions, and lack of blinding of patients and treating therapists to allocation may have introduced bias.

In addition, none of the participants received corticosteroids. Although this was consistent with usual practice in Argentina and enhanced sample uniformity, generalizability to patients who receive corticosteroids is uncertain. Most patients with Bell's palsy are prescribed oral corticosteroids because many evidence-based guidelines recommend oral corticosteroids be started within 72 hours of onset of paralysis in patients with Bell's palsy to shorten the duration of paralysis and improve recovery.[46-48] Furthermore, lack of clear information on pulse duration and current intensity over the course of therapy, limits replication of the procedure. This study demonstrates that selective electrical stimulation accelerates recovery from Bell's palsy in patients who do not receive corticosteroids or do not receive them in a timely fashion. Based on proposed mechanisms of action, including slowing muscle atrophy and promoting nerve recovery, we expect electrical stimulation would have a similar, although possibly more muted, effect on recovery from Bell's palsy in those treated with corticosteroids. A future study, where participants are treated with corticosteroids, patients at high risk for poor outcome (e.g. with diabetes or complete paralysis) are included or selected for, with clear complete description of all treatment parameters and predetermined follow-up times, and an intent to treat analysis, would further improve our understanding of the optimal role and impacts of selective electrical muscle stimulation in the treatment of Bell's palsy.

In conclusion, this study supports the efficacy of selective electrical muscle stimulation in the treatment of acute Bell's palsy. The stimulation protocol used in the study accelerated recovery from flaccid paralysis, halving the recovery time, and resulted in similar excellent long-term outcomes with regards to static facial expression, dynamic facial movement and synkinesis.

## List of acronyms

HB - House Brackmann
IQR - interquartile range
SD - standard deviation

## Contributions of Authors

LLJ, AZC: Provided and cared for study participants and collected data, participated in interpreting data; ADP: Created the study protocol, supervised study, helped draft the manuscript; VC: Served as a scientific advisor for study protocol and study designed, aided in manuscript preparation; ML and MC: Participated as scientific advisors for data analysis and interpretation, prepared the manuscript; MC: volunteered to demonstrate the digital selective electrical muscle stimulation technique; CL and CJ: Served as blinded raters for eFACE outcome; AH: Provided statistical analysis design and conducted the analysis and reviewed the final manuscript. All authors agree to be accountable for the work, critically reviewed for content and accuracy and gave final approval. All authors have read and approved the final edited typescript.

## Acknowledgments

We wish to thank the treating physical therapists in the Kinesiology Department at the National University of the Northeast [Universidad Nacional del Nordeste (UNNE)], Corrientes, Argentina for their participation in the study including: Lorena Acosta, Wilson Tomadin, Walter Vera, Leandro Vargas, Silvia Villaboas, Matías Shuster, José Buzzelato, and Karina Lescano. We also thank all persons for their time and study participation.

## Funding

The authors received no specific funding for this work.

## Conflict of Interest

The authors declare no conflicts of interest.

## Ethical Publication Statement

We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

## Corresponding Author

Myriam Loyo, MD, MCR; Associate Professor; Co-director Facial Nerve Center. Department of Otolaryngology – Head and Neck Surgery, Oregon Health & Science University, 3303 SW Bond Ave., Portland, OR 97239, USA. Phone 001 503-494-5678
Fax 001 (503) 346- 6826.
ORCHID iD: 0000-0003-1590-7054
Email: loyo@ohsu.edu

*E-mails and ORCID iD of co-authors*

*Antonio Di Pietro: tonydipi1@gmail.com*
*ORCID iD: 0009-0009-8286-0541*
*Michelle Cameron: cameromi@ohsu.edu*
*ORCID iD: 0000-0001-7971-4679*
*Vilma Campana: campanav@hotmail.com*
*ORCID iD: 0000-0001-6742-8640*
*Laura Leyes: lauraleyes@med.unne.edu.ar*
*ORCID iD: 0000-0001-5973-1084*
*Jessica Andrea Isabel Zalazar Cinat: jessicazalazarcinat@med.unne.edu.ar*
*ORCID iD: 0000-0001-6945-6768*
*Carly Lochala: lochala@ohsu.edu*
*ORCID iD: 0009-0001-0365-3264*
*Christopher Z Johnson: czjohnson@gmail.com*
*ORCID iD: 0000-0002-7364-0936*
*Andrea Hildebrand: hildeand@ohsu.edu*
*ORCID iD: 0000-0002-1277-1588*

## References

1. Bleicher JN, Hamiel S, Gengler JS, Antimarino J. A survey of facial paralysis: etiology and incidence. Ear Nose Throat J. Jun 1996;75(6):355-8. PMID: 8689964
2. Holland NJ, Bernstein JM. Bell's palsy. BMJ Clin Evid. Apr 9 2014;2014:1204. PMID: 24717284; PMCID: PMC3980711.
3. Warner MJ, Hutchison J, Varacallo M. Bell Palsy. 2023 Aug 17. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan–. PMID: 29493915.4.Peitersen E. Bell's palsy: the spontaneous course of 2,500 peripheral facial nerve palsies of different etiologies. Acta Otolaryngol Suppl. 2002;(549):4-30. PMID: 12482166.
5. Zalazae Cinat JDP, AA.; Leyes, LE.; Vargas, LE.; and Vera WD. Sincinesias Asociadas a Paralisis Faciales. Libro de Articulos Cientificos en Salud 2019 Facultad de Medicina Universidad Nacional del Nordeste. 2019:84-87. Spanish.
6. Husseman J, Mehta RP. Management of synkinesis. Facial Plast Surg. May 2008;24(2):242-9. doi:10.1055/s-2008-1075840. PMID: 18470836.
7. Kanaya K, Ushio M, Kondo K,Hagisawa M, Suzukawa K, Yamaguchi T, Tojima H, Suzuki M, Yamasoba T.. Recovery of facial movement and facial synkinesis in Bell's palsy patients. Otol Neurotol. Aug 2009;30(5):640-4. doi:10.1097/MAO.0b013e3181ab31af. PMID: 19574944.
8. Bistolfi A, Zanovello J, Ferracini R,Allisiardi F, Lioce E, Magistroni E, Berchialla P, Da Rold I, Massazza G. . Evaluation of the Effectiveness of Neuromuscular Electrical Stimulation After Total Knee Arthroplasty: A Meta-Analysis. Am J Phys Med Rehabil. Feb 2018;97(2):123-130. doi:10.1097/PHM.0000000000000847.PMID: 29016401.
9. Nussbaum EL, Houghton P, Anthony J, Rennie S, Shay BL, Hoens AM. Neuromuscular Electrical Stimulation for Treatment of Muscle Impairment: Critical Review and Recommendations for Clinical Practice. Physiother Can. 2017;69(5):1-76. doi:10.3138/ptc.2015-88. PMID: 29162949; PMC5683854
10. Hong Z, Sui M, Zhuang Z, Liu H, Zheng X, Cai C, Jin D. . Effectiveness of Neuromuscular Electrical Stimulation on Lower Limbs of Patients With Hemiplegia After Chronic Stroke: A Systematic Review. Arch Phys Med Rehabil. May 2018;99(5):1011-1022 e1. doi:10.1016/j.apmr.2017.12.019. Epub 2018 Jan 31. PMID: 29357280.
11. Wang LC, Wei WY, Ho PC. Short-Term Cortical Electrical Stimulation during the Acute Stage of Traumatic Brain Injury Improves Functional Recovery. Biomedicines. Aug 12 2022;10(8) doi:10.3390/biomedicines10081965.PMID: 36009512; PMCID: PMC9405844
12. Salazar AP, Pagnussat AS, Pereira GA, Scopel G, Lukrafka JL. Neuromuscular electrical stimulation to improve gross motor function in children with cerebral palsy: a meta-analysis. Braz J Phys Ther. Sep-Oct 2019;23(5):378-386. doi:10.1016/j.bjpt.2019.01.006. PMID: 30712812; PMCID: PMC6823719
13. Munn A CM, and Loyo M. Trends in Electric Stimulation for Facial Paralysis: Electronic survey of Physical therapists in Oregon. Arch Physiotherapy and Rehab. 2020;3:001-008.
14. Shafshak TS. The treatment of facial palsy from the point of view of physical and rehabilitation medicine. Eura Medicophys. Mar 2006;42(1):41-7. PMID: 16565685.
15. Diels HJ. Facial paralysis: is there a role for a therapist? Facial Plast Surg. 2000;16(4):361-4. doi:10.1055/s-2000-15546. PMID: 11460303.
16. Alakram P, Puckree T. Effects of electrical stimulation on House-Brackmann scores in early Bell's palsy. Physiother Theory Pract. Apr 22 2010;26(3):160-6. doi:10.3109/09593980902886339. PMID: 20331372.
17. Mosforth J, Taverner D. Physiotherapy for Bell's palsy. Br Med J. Sep 13 1958;2(5097):675-7. doi:10.1136/bmj.2.5097.675. PMID: 13572865; PMCID: PMC2026410
18. Manikandan N. Effect of facial neuromuscular re-education on facial symmetry in patients with Bell's palsy: a randomized controlled trial. Clin Rehabil. Apr 2007;21(4):338-43. doi:10.1177/0269215507070790. PMID: 17613574.
19. Kim J, Choi JY. The effect of subthreshold continuous electrical stimulation on the facial function of patients with Bell's palsy. Acta Otolaryngol. 2016;136(1):100-5. doi:10.3109/00016489.2015.1083121. Epub 2015 Sep 23. PMID: 26399994.
20. Tuncay F, Borman P, Taser B, Ünlü İ, I, Samim E. Role of electrical stimulation added to conventional therapy in patients with idiopathic facial (Bell) palsy. Am J Phys Med Rehabil. Mar 2015;94(3):222-8. doi:10.1097/PHM.0000000000000171. PMID: 25171666.
21. Flores PF MR, Haro LG. Idiopathic peripheral facial paralysis treatment physic therapy versus prednisone [Tratamiento de la paralysis facial peripherica idiopatica: terapia fisica versus prednisone]. Revista Medica del Instituto Mexicano del Seguro Social 1998 1998;36 (3):217-21. Spanish.
22. Ikeda M, Abiko Y, Kukimoto N, Omori H, Nakazato H, Ikeda K. Clinical factors that influence the prognosis of facial nerve paralysis and the magnitudes of influence. Laryngoscope. May 2005;115(5):855-60. doi:10.1097/01.MLG.0000157694.57872.82. PMID: 15867653.

23. Marotta N, Demeco A, Inzitari MT, Caruso MG, Ammendolia A. Neuromuscular electrical stimulation and shortwave diathermy in unrecovered Bell palsy: A randomized controlled study. Medicine (Baltimore). Feb 2020;99(8):e19152. doi:10.1097/MD.0000000000019152. PMID: 32080092; PMCID: PMC7034718
24. Kanerva M, Poussa T, Pitkaranta A. Sunnybrook and House-Brackmann Facial Grading Systems: intrarater repeatability and interrater agreement. Otolaryngol Head Neck Surg. Dec 2006;135(6):865-71. doi:10.1016/j.otohns.2006.05.748. PMID: 17141075.
25. Maddocks M, Gao W, Higginson IJ, Wilcock A. Neuromuscular electrical stimulation for muscle weakness in adults with advanced disease. Cochrane Database Syst Rev. Jan 31 2013;(1):CD009419. doi:10.1002/14651858.CD009419.pub2. Update in: Cochrane Database Syst Rev. 2016 Oct 17;10 :CD009419. PMID: 23440837.
26. Kittelson AJ, Stackhouse SK, Stevens-Lapsley JE. Neuromuscular electrical stimulation after total joint arthroplasty: a critical review of recent controlled studies. Eur J Phys Rehabil Med. Dec 2013;49(6):909-20. Epub 2013 Nov 28. PMID: 24285026.
27. Kloth LC, Feedar JA. Acceleration of wound healing with high voltage, monophasic, pulsed current. Phys Ther. Apr 1988;68(4):503-8. doi:10.1093/ptj/68.4.503. Erratum in: Phys Ther 1989 Aug;69(8):702. PMID: 3258429.
28. Barnes R, Shahin Y, Gohil R, Chetter I. Electrical stimulation vs. standard care for chronic ulcer healing: a systematic review and meta-analysis of randomised controlled trials. Eur J Clin Invest. Apr 2014;44(4):429-40. doi:10.1111/eci.12244. PMID: 24456185.
29. Hadlock T, Lindsay R, Edwards C, et al. The effect of electrical and mechanical stimulation on the regenerating rodent facial nerve. Laryngoscope. Jun 2010;120(6):1094-102. doi:10.1002/lary.20903. PMID: 20513023.
30. Gordon T, Chan KM, Sulaiman OA, Udina E, Amirjani N, Brushart TM. Accelerating axon growth to overcome limitations in functional recovery after peripheral nerve injury. Neurosurgery. Oct 2009;65(4 Suppl):A132-44. doi:10.1227/01.NEU.0000335650.09473.D3. PMID: 19927058.
31. Banks CA, Jowett N, Azizzadeh B, eurskens C, Bhama P, Borschel G, Coombs C, Coulson S, Croxon G, Diels J, Fattah A, Frey M, Gavilan J, Henstrom D, Hohman M, Kim J, Marres H, Redett R, Snyder-Warwick A, Hadlock T. Worldwide Testing of the eFACE Facial Nerve Clinician-Graded Scale. Plast Reconstr Surg. Feb 2017;139(2):491e-498e. doi:10.1097/PRS.0000000000002954.PMID: 28121888.
32. Banks CA, Jowett N, Hadlock TA. Test-Retest Reliability and Agreement Between In-Person and Video Assessment of Facial Mimetic Function Using the eFACE Facial Grading System. JAMA Facial Plast Surg. May 1 2017;19(3):206-211. doi:10.1001/jamafacial.2016.1620. PMID: 28006048; PMCID: PMC5815128
33. Beurskens CH, Heymans PG. Positive effects of mime therapy on sequelae of facial paralysis: stiffness, lip mobility, and social and physical aspects of facial disability. Otol Neurotol. Jul 2003;24(4):677-81. doi:10.1097/00129492-200307000-00024. PMID: 12851564.
34. Beurskens CH, Heymans PG. Mime therapy improves facial symmetry in people with long-term facial nerve paresis: a randomised controlled trial. Aust J Physiother. 2006;52(3):177-83. doi:10.1016/s0004-9514(06)70026-5. PMID: 16942452.
35. Baricich A, Cabrio C, Paggio R, Cisari C, Aluffi P. Peripheral facial nerve palsy: how effective is rehabilitation? Otol Neurotol. Sep 2012;33(7):1118-26. doi:10.1097/MAO.0b013e318264270e. PMID: 22872180.
36. Di Pietro A, Benitez IA. Resultados del tratemiento kinesico en un caso de doble paralysis facial. Revista de la Facultad de Medicina Universidad del Nordeste. 2013;XXXIII(2):22-26. Spanish.
37. Banks CA, Bhama PK, Park J, Hadlock CR, Hadlock TA. Clinician-Graded Electronic Facial Paralysis Assessment: The eFACE. Plast Reconstr Surg. Aug 2015;136(2):223e-230e. doi:10.1097/PRS.0000000000001447. PMID: 26218397.
38. StataCorp. Stata Statistical Software: Release 15. College Station TSL. Stat Statisctial Software:. 2017.
39. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing V, Austria. URL https://www.R-project.org/. 2020.
40. Wickham. H. ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York. 2016.
41. Kim KM, Croy T, Hertel J, Saliba S. Effects of neuromuscular electrical stimulation after anterior cruciate ligament reconstruction on quadriceps strength, function, and patient-oriented outcomes: a systematic review. J Orthop Sports Phys Ther. Jul 2010;40(7):383-91. doi:10.2519/jospt.2010.3184. PMID: 20592480
42. Taradaj J, Halski T, Kucharzewski M,Walewicz K, Smykla A, Ozon M, Slupska L, Dymarek R, Ptaszkowski K, Rajfur J, Pasternok M. . The effect of neuromuscular electrical stimulation on quadriceps strength and knee function in professional soccer players: return to sport after ACL reconstruction. Biomed Res Int. 2013;2013:802534. doi:10.1155/2013/802534.

Epub 2013 Dec 5. PMID: 24381943; PMCID: PMC3870113.
43. Moran U, Gottlieb U, Gam A, Springer S. Functional electrical stimulation following anterior cruciate ligament reconstruction: a randomized controlled pilot study. J Neuroeng Rehabil. Jul 12 2019;16(1):89. doi:10.1186/s12984-019-0566-0. PMID: 31299999; PMCID: PMC6626389
44. Puls WC, Jarvis JC, Ruck A, Lehmann T, Guntinas-Lichius O, Volk GF. Surface electrical stimulation for facial paralysis is not harmful. Muscle Nerve. Mar 2020;61(3):347-353. doi:10.1002/mus. 26784. PMID: 31875972.
45. Kurz A, Volk GF, Arnold D, Schneider-Stickler B, Mayr W, Guntinas-Lichius O. Selective Electrical Surface Stimulation to Support Functional Recovery in the Early Phase After Unilateral Acute Facial Nerve or Vocal Fold Paralysis. Front Neurol. 2022;13:869900. doi:10.3389/fneur.2022.869900. PMID: 35444611; PMCID: PMC9013944.
46. Baugh RF, Basura GJ, Ishii LE, Schwartz SR, Drumheller CM, Burkholder R, Deckard NA, Dawson C, Driscoll C, Gillespie MB, Gurgel RK, Halperin J, Khalid AN, Kumar KA, Micco A, Munsell D, Rosenbaum S, Vaughan W. Clinical practice guideline: Bell's palsy. Otolaryngol Head Neck Surg. Nov 2013;149(3 Suppl):S1-27. doi:10.1177/0194599813505967.PMID: 24189771.
47. de Almeida JR, Guyatt GH, Sud S, Dorion J, Hill MD, Kolber MR, Lea J, Reg SL, Somogyi BK, Westerberg BD, White C, Chen JM; Management of Bell palsy: clinical practice guideline. CMAJ. Sep 2 2014;186(12):917-22. doi:10.1503/cmaj. 131801. PMID: 24934895; PMCID: PMC4150706.
48. Gronseth GS, Paduga R, American Academy of Neurology. Evidence-based guideline update: steroids and antivirals for Bell palsy: report of the Guideline Development Subcommittee of the American Academy of Neurology. Neurology. Nov 27 2012;79(22):2209-13. doi:10.1212/WNL. 0b013e318275978c. Epub 2012 Nov 7. PMID: 23136264.

## Disclaimer

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article or claim that may be made by its manufacturer is not guaranteed or endorsed by the publisher.

Submission: August 02, 2023
Revision received: September 26, 2023
Accepted for publication: September 28, 2023

Eur J Transl Myol 33 (4) 11630, 2023 doi: 10.4081/ejtm.2023.11630

***Supplementary materials:***

*Regression Model Specification*

Mixed effects linear regression models were built to characterize the between-group difference in trajectory over time for each of the static, dynamic, and synkinesis eFACE scores. These models included fixed effects for treatment group, days since onset of Bell's Palsy at baseline, visit, and weeks elapsed at each visit, and a random participant effect to account for within-participant correlations over repeated measurements. Between-group difference at each follow-up visit was characterized by the interaction between treatment group and visit. The hypothesis of interest was whether a group-by-visit interaction was present at either visit.

$$Y_{ij} = \beta_0 + \beta_1(treatment\ group)_i + \beta_2(days\ since\ onset)_i + \beta_3(visit\ 1)_{ij} + \beta_4(visit\ 2)_{ij} + \beta_5(visit\ 1 * treatment\ group)_{ij} + \beta_6(visit\ 2 * treatment\ group)_{ij} + \beta_7(visit\ 1 * weeks\ elapsed)_{ij} + \beta_8(visit\ 2 * weeks\ elapsed)_{ij} + b_{ij} + \varepsilon_{ij}$$

Where:
i = participant (1, 2, … , 38)
j = visit (baseline, discharge, six-month follow up)
Y = eFACE score (static, dynamic, or synkinesis)
treatment group: 1 if treatment group = selective electric muscle stimulation, 0 otherwise
visit 1: 1 if visit = discharge, 0 otherwise
visit 2: 1 if visit = six-month follow up, 0 otherwise
b: participant random effect
ε: measurement error

To test whether there is a group effect at discharge, we test the hypothesis:
$B_5 = 0$ vs. $\beta_5 \neq 0$

To test whether there is a group effect at six-month follow up, we test the hypothesis:
$B_6 = 0$ vs. $\beta_6 \neq 0$

*Regression Model Output*

Regression output for mixed effects linear regression of static, dynamic, and synkinetic eFACE scores. *Group* refers to the selective electric muscle stimulation group (control group as reference). In these analyses, we are most interested in between-group differences (group effect) at discharge and 6-month follow up (bolded).

Table S1: Regression output of static eFACE score

| | Coefficient | Standard Error | 95% Confidence Interval | p-value |
|---|---|---|---|---|
| Intercept ($\beta_0$) | 75.58 | 3.00 | 69.70 – 81.46 | <0.01 |
| Group ($\beta_1$) | 5.16 | 3.33 | -1.37 – 11.69 | 0.12 |
| Days since onset ($\beta_2$) | -0.04 | 0.20 | -0.42 – 0.35 | 0.85 |
| Change from baseline at: | | | | |
| Discharge ($\beta_3$) | 17.59 | 4.16 | 9.44 – 25.74 | <0.01 |
| 6-month follow up ($\beta_4$) | 7.82 | 18.98 | -29.38 – 45.02 | 0.68 |
| Group effect at: | | | | |
| Discharge ($\beta_5$) | **-3.95** | **4.14** | **-12.06 – 4.16** | **0.34** |
| 6-month follow up ($\beta_6$) | **-1.81** | **4.14** | **-9.91 – 6.30** | **0.66** |
| Weeks from baseline until: | | | | |
| Discharge ($\beta_7$) | -0.44 | 0.60 | -1.62 – 0.74 | 0.46 |
| 6-month follow up ($\beta_8$) | 0.30 | 0.60 | -0.88 – 1.48 | 0.50 |

Table S2: Regression output of dynamic eFACE score

| | Coefficient | Standard Error | 95% Confidence Interval | p-value |
|---|---|---|---|---|
| Intercept ($\beta_0$) | 46.53 | 4.18 | 38.33 – 54.72 | <0.01 |
| Group ($\beta_1$) | -5.31 | 4.59 | -14.31 – 3.69 | 0.25 |
| Days since onset ($\beta_2$) | -0.29 | 0.28 | -0.84 – 0.25 | 0.30 |
| Change from baseline at: | | | | |
| Discharge ($\beta_3$) | 44.76 | 5.55 | 33.89 – 55.63 | <0.01 |
| 6-month follow up ($\beta_4$) | 48.91 | 25.53 | -1.12 – 98.95 | 0.06 |
| Group effect at: | | | | |
| Discharge ($\beta_5$) | **8.44** | **5.47** | **-2.28 – 19.16** | **0.12** |
| 6-month follow up ($\beta_6$) | **10.41** | **5.47** | **-0.31 – 21.14** | **0.06** |
| Weeks from baseline until: | | | | |
| Discharge ($\beta_7$) | -1.07 | 0.81 | -2.66 – 0.52 | 0.19 |
| 6-month follow up ($\beta_8$) | -0.13 | 0.81 | -1.72 – 1.46 | 0.87 |

Table S3: Regression output of synkinetic eFACE score

| | Coefficient | Standard Error | 95% Confidence Interval | p-value |
|---|---|---|---|---|
| Intercept ($\beta_0$) | 100.43 | 0.84 | 98.78 – 102.08 | <0.01 |
| Group ($\beta_1$) | 0.14 | 1.07 | -1.95– 2.24 | 0.89 |
| Days since onset ($\beta_2$) | -0.06 | 0.06 | -0.18 – 0.06 | 0.30 |
| Change from baseline at: | | | | |
| Discharge ($\beta_3$) | -0.67 | 1.01 | -2.64 – 1.30 | 0.51 |
| 6-month follow up ($\beta_4$) | 34.94 | 5.70 | 23.77 – 46.11 | <0.01 |
| Group effect at: | | | | |
| Discharge ($\beta_5$) | **-1.44** | **1.39** | **-4.15 – 1.28** | **0.30** |
| 6-month follow up ($\beta_6$) | **-0.15** | **1.39** | **-2.86 – 2.57** | **0.92** |
| Weeks from baseline until: | | | | |
| Discharge ($\beta_7$) | -0.11 | 0.20 | -0.50 – 0.27 | 0.57 |
| 6-month follow up ($\beta_8$) | -1.28 | 0.20 | -1.67 – -0.90 | <0.01 |