Puckering and Blowing Facial Expressions in People With Facial Movement Disorders

Rachel L Denlinger, Jessie M VanSwearingen, Jeffrey F Cohn, Karen L Schmidt

Background and Purpose. People with facial movement disorders are instructed to perform various facial movements as part of their physical therapy rehabilitation. A difference in the movement of the orbicularis oris muscle has been demonstrated among people without facial nerve impairments when instructed to "pucker your lips" and to "blow, as if blowing out a candle." The objective of this study was to determine whether the within-subject difference between "pucker your lips" and "blow, as if blowing out a candle" found in people without facial nerve impairments is present in people with facial movement disorders.

Subjects and Methods. People (N=68) with unilateral facial movement disorders were observed as they produced puckering and blowing movements. Automated facial image analysis of both puckering and blowing was used to determine the difference between facial actions for the following movement variables: maximum speed, amplitude, duration, and corresponding asymmetry.

Results. There was a difference between the amplitudes of movement for puckering and blowing. "Blow, as if blowing out a candle" produced a larger amplitude of movement.

Discussion and Conclusion. The findings demonstrate that puckering and blowing movements in people with facial movement disorders differ in a manner that is consistent with differences found in people who are healthy. This information may be useful in the assessment of and intervention for facial movement disorders affecting the lower face.

RL Denlinger, BS, is Research Assistant, Department of Psychology, University of Pittsburgh, Pittsburgh, Pennsylvania.

JM VanSwearingen, PT, PhD, is Associate Professor, Department of Physical Therapy, University of Pittsburgh.

JF Cohn, PhD, is Professor, Department of Psychology, University of Pittsburgh.

KL Schmidt, PhD, is Assistant Professor, Department of Psychiatry, University of Pittsburgh, 121 University Pl, Pittsburgh, PA 15260 (USA). Address all correspondence to Dr Schmidt at: kschmidt@pitt.edu.

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A person's face is his or her first form of identification. The face is the physical attribute that distinguishes a person from the rest of the world and is an essential component of how an individual interacts with others, sustains life, and manages his or her environment. People with facial movement disorders report physical function and psychosocial distress related to their physical appearance, difficulty pronouncing specific words or sounds, drinking from a cup, or even chewing food.[1–5]

Because routine tasks, such as eating or drinking, that depend on healthy facial functioning can be very challenging for people with facial movement disorders, improving lip movement and movement control is an important target of intervention. Frequently, the treatment for such disorders includes facial physical therapy for facial rehabilitation, with the ultimate goal of increasing voluntary movement of the facial muscles. Although treatment programs may differ from therapist to therapist regarding the specific therapeutic approach, many include a series of facial actions for the patient to perform both during the therapy session and as a part of a home exercise program.[6,7]

One facial muscle, the obicular muscle of the mouth (orbicularis oris), is responsible for both puckering and blowing facial actions.[8] However, because the contexts of the actions differ, we considered the possibility that the movements may differ as well. We previously compared the movements of puckering and blowing in adults without facial nerve impairments.[9] Participants were interviewed and asked to perform a series of facial actions, including "pucker your lips" and "blow, as if blowing out a candle". The facial actions were video recorded, digitized, and measured by use of automated facial image analysis.[9] A repeated-measures analysis of variance with facial action (pucker or blow) as a within-participant factor revealed a significant lip movement difference between puckering and blowing. In a comparison of the blow facial action with the pucker facial action, an instruction to "blow, as if blowing out a candle" produced expressions with larger amplitudes, less asymmetry, and longer durations.[9] Such differences in performance may not be identified in people with facial movement disorders because most assessments for function of the muscles of facial expression have used only movements such as puckering and have not included deliberate functions, such as blowing,[10] in the evaluation scheme. Focused movement instructions may lead to better assessment and better therapy results as well as an increase in the understanding of the basic processes of deliberate facial movements in people with facial movement disorders.

Schmidt and colleagues[11] also have found a consistent relationship between the amplitude of movement and the maximum velocity of the lip corner movement during both facial actions. The relationship has been found in studies involving spontaneous movements as well and has been interpreted as evidence of the stereotyped nature of human facial expressions.[11] Speed and amplitude of movement are related in adults who are healthy performing both deliberate and spontaneous facial movements, but it is not known whether the relationship holds true for facial movements in people with facial movement disorders. A consistent relationship between speed and amplitude of movement on both sides of the face has been shown for puckering and blowing in adults who are healthy.[9] It is not known whether the same relationship of speed and amplitude can be expected in the lip movements of people with facial movement disorders. Because of the aforementioned relationship between maximum speed and amplitude in people without facial movement disorders, we expected to find a similar relationship in people with such disorders in the present study. Lip movements on the impaired side of the face, however, may not exhibit the same type of relationship between movement measures.

We compared 2 facial actions in different contexts of instructions to determine the facial movement and instructional context producing the greatest facial motion. On the basis of previous studies, we expected that puckering facial action, which focuses attention on movement of the lips specifically rather than on the context in which a task is accomplished (eg, blowing out a candle), would be smaller in amplitude, smaller in maximum speed, and shorter in duration in people with facial movement disorders. In addition, we expected that puckering facial action would have greater asymmetry of movement than blowing facial action for all 3 measures (ie, amplitude, maximum speed, and duration).

Method

Participants

Subjects were 73 people (43 women and 30 men) who had a unilateral facial movement disorder and who were receiving physical therapy at the University of Pittsburgh Facial Nerve Center. At the time of participation in the present study, all subjects were enrolled in a larger study of psychosocial health and facial nerve disorders (FIND study) at the University of Pittsburgh. Videotape from 2 subjects was not available; therefore, these subjects were excluded from the study. Another 3 subjects were excluded because their videotape images could not be successfully analyzed with Automated Facial Image Analysis (AFIA) software. In total, 5 subjects were excluded from the overall group of FIND subjects.

Subjects ranged in age from 18 to 65 years, with a mean age of 43 years. The medical diagnoses of the 73 original subjects were as follows: Bell palsy (n=33), Ramsay-Hunt syndrome (n=9), acoustic neuroma (n=9), trauma (n=6), pregnancy-onset Bell palsy (n=5), other tumors (n=5), and other conditions (n=6) (Tab. 1). The average length of time since the onset of the facial movement disorder was 25 months. Twenty-two participants (32%) had left-side facial paralysis, and 46 participants (68%) had right-side facial paralysis. All participants were compensated for their participation in the research project.

Table 1.
Participant Demographics by Facial Movement Disorder

Facial Movement Disorder	No. of Subjects	Age, $\bar{X}$ (SD)	Onset (mo), $\bar{X}$
Bell palsy	33	44.62 (14.86)	21
Ramsay-Hunt syndrome	9	46.46 (9.21)	10
Acoustic neuroma	9	44.71 (11.28)	55
Trauma	6	24.73 (3.21)	46
Pregnancy-onset Bell palsy	5	41.94 (6.64)	35
Other conditions[a]	6	50.80 (13.22)	12
Other tumors[b]	5	50.83 (9.56)	12
Total	73	43.95 (13.48)	25

[a] Lyme disease (n=1), microvascular depression (n=2), Guillain-Barré syndrome (n=1), congenital facial palsy (n=1), unknown condition (n=1).
[b] Parotid gland tumor (n=1), osteosarcoma excision (n=1), hemangioma excision (n=1), superficial facial tumors (n=2).

Procedure

After providing informed consent for participation in the study, participants were video recorded while performing a number of voluntary facial movements and tasks. Each participant was seated in a chair. Video recording was frontal and was done with a Panasonic DVX100 miniDV camcorder* mounted on a tripod and recording at 30 frames per second at a distance of approximately 1.5 to 1.8 m (5–6 ft) from the subject. Head motion was minimal and was controlled for by the video data processing method described below. Participants were instructed to voluntarily perform several facial actions. The primary focus of the present study was participants' responses to requests for 2 facial actions: "pucker your lips" and "blow, as if blowing out a candle." Participants performed puckering first and blowing second. These facial actions were performed and video recorded in the context of a facial evaluation that included multiple facial actions involving upper, middle, and lower facial regions. Both of the actions were coded as Action Unit 18 (AU18) according to the Facial Action Coding System (FACS), a detailed observational coding system for facial movement that is based on the activity of individual muscles.[12,13] One certified FACS coder provided a consensus code of AU18 for each video sequence analyzed (Fig. 1).

* Panasonic Corp of North America, 1 Panasonic Way, Secaucus, NJ 07094.

Digital Video Processing and Automated Tracking of Facial Expression

Digital video was exported to an image sequence format by use of Adobe Premiere 6.5,† which produced sets of pixel arrays (individual frames) of 640×480 with 24-bit precision for color values. Thirty video frames per second were captured. The initial and final frames of the sequences were reliably coded as neutral (AU0) facial expressions

† Adobe Systems Inc, 345 Park Ave, San Jose, CA 95110.

Figure 1.
Examples of neutral expression and puckering and blowing movements in an individual with facial movement disorder (facial Action Unit 0 and facial Action Unit 18, according to the Facial Action Coding System[12,13]).

Figure 2.
Feature points that capture the movement of the face with Automated Facial Image Analysis software.

(agreement=100%).[12,13] The entire sequence of images for both facial actions was analyzed.

Automated Face Image Analysis software was used to track the movement of the lips.[14] The AFIA system provides automated head stabilization to create stabilized face images for tracking, thus separating facial movements attributable to expression changes from facial movements attributable to rigid head movements.[15] Because rigid head movements are controlled, any feature point displacement is attributable to lip movement.[15] Feature points were manually marked in the first frame of each sequence. In the AFIA system, the feature points affect only the video-recorded image and are not physically placed on the participant's skin. A previous study of people with facial movement disorders established very high reliability between the position of traditional physical facial markers on the skin and the position of feature points in the AFIA system.[16] A feature point is a marker placed at a specific location (eg, the edges of the lips or the corners of the eyes) on a facial image in order to monitor the movements of the face. The 10 feature points that capture the movement of the lips are shown in Figure 2. The feature points included in the analyses in this study were the following: both lip corners, 2 points on the left side of the upper lip, 2 points on the right side of the upper lip, 2 points on the left side of the lower lip, and 2 points on the right side of the lower lip. The middle lip points were excluded from the analysis because the points did not belong to either side of the face. The Lucas-Kanade algorithm for feature point tracking was used to automatically obtain x-y coordinates for the feature points in subsequent frames.[17]

The displacement of each pixel coordinate (r) from its initial position (x, y) was calculated as follows:

$$r = \sqrt{x^2 + y^2}.$$

In order to facilitate comparisons among participants, values of r were divided by the initial (neutral) value for the width of the mouth from the left lip corner to the right lip corner. Proportional values of r were then summed for all feature points tracked on the left side of the mouth to create a composite variable combining movements at all 5 lateral points including the mouth corner. The same process was performed for feature points on the right side of the mouth. From these summed left and right composite proportional variables, onset start and end times were obtained for each side of the mouth during expression. We defined onset duration of the expression as the longest continuous increase in seconds in composite displacement values over the course of the expression.[9]

Measurement

Composite displacement values for the impaired and unimpaired sides of the face were analyzed to obtain values for the amplitude and the maximum speed of initial onset. The duration of onset also was analyzed for the right and left sides. Amplitude was established by finding the difference between the composite displacement values at the beginning and the end of the defined movement onset period. Maximum speed of onset for impaired and unimpaired sides was established by finding the maximum frame-to-frame difference between the composite displacement values. For determining asymmetry, the differences between impaired and unimpaired values of amplitude, maximum speed, and duration were calculated. All variables were determined for the facial actions of puckering and blowing.

Data Analysis

Descriptive statistics were determined for each dependent variable. A repeated-measures analysis for within-participant differences was conducted with facial action (puckering or blowing) and impairment status (impaired or unimpaired) as factors. Amplitude, maximum speed, duration, amplitude asymmetry, maximum speed asymmetry, and duration asymmetry were the outcome measures for the analyses. Correlational analyses (Pearson product moment correlation) of the relationship between maximum speed and amplitude of movement on both sides of the face (impaired and unimpaired) were conducted for both puckering and blowing actions, and the proportion of the variance in amplitude accounted for by maximum speed was reported as R^2.

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Results

Puckering and Blowing Movements

Descriptive statistics for the composite movement variables amplitude, maximum speed, and duration of movement were determined (Tab. 2). As expected, blowing showed a higher amplitude of movement than did puckering on the impaired side (for blowing: $\bar{X}$=0.500, SD=0.252; for puckering: $\bar{X}$=0.352, SD=0.155) and on the unimpaired side (for blowing: $\bar{X}$=0.550, SD=0.265; for puckering: $\bar{X}$=0.475, SD=0.225). Repeated-measures analysis with facial action (pucker or blow) and impairment status (impaired or unimpaired) as factors for within-participant differences demonstrated that blowing resulted in lip movements of greater amplitude than did puckering (F=10.233; *df*=1,67; *P*=.002).

Impairment attributable to unilateral facial movement disorder also affected movement in puckering and blowing. Amplitude of movement (F=21.262; *df*=1,67; *P*<.001), maximum speed (F=17.413; *df*=1,67; *P*<.001), and duration of movement (F=6.548; *df*=1,67; *P*=.013) were greater on the unimpaired side than on the impaired side of the face for both puckering and blowing actions (Tab. 2).

Table 2.
Comparison of Amplitude, Maximum Speed, and Duration of Movement for Puckering and Blowing

	Facial Action	
	Puckering	Blowing
Movement Variable	$\bar{X}$ (SD)	$\bar{X}$ (SD)
Amplitude (proportional change)		
Impaired	0.352 (0.155)	0.500[a] (0.252)
Unimpaired	0.475 (0.225)	0.550[a] (0.265)
Maximum speed (maximum change/0.033 s)		
Impaired	0.060 (0.031)	0.068 (0.034)
Unimpaired	0.074 (0.041)	0.075 (0.039)
Duration (s)		
Impaired	0.634 (0.280)	0.689 (0.281)
Unimpaired	0.708 (0.308)	0.756 (0.286)

[a] *P*<.01.

Asymmetry of Movement in Puckering and Blowing

Unilateral facial movement disorder produced a degree of asymmetry in movement for both puckering and blowing actions. Asymmetry of movement for 3 composite movement variables, however, did not differ between puckering and blowing actions.

Relationship Between Maximum Speed and Amplitude of Puckering and Blowing Movements

As in an earlier study of people without facial movement disorders, maximum speed and amplitude of movement were related in both puckering and blowing, although a significant amount of variance in amplitude remained unexplained by the maximum speed of movement. There were moderate correlations between maximum speed and amplitude for puckering (for the impaired side of the face: *r*=.700; *P*<.001; R^2=.488; F=62.5; *df*=1,66; *P*<.001; for the unimpaired side of the face: *r*=.760; *P*<.001; R^2=.578; F=90.5; *df*=1,66). There were similar correlations between maximum speed and amplitude for blowing (for the impaired side: *r*=.676; *P*<.001; R^2=.456; F=55.4; *df*=1,66; *P*<.001; for the unimpaired side: *r*=.648; *P*<.001; R^2=.420; *P*<.001).

Discussion

The instruction to "blow, as if blowing out a candle," produced larger amplitude of movement than "pucker your lips" when given to people with a unilateral facial movement disorder. Specifically, the response to a request for blowing produced greater facial movement than a response to the request for puckering. Blowing, a facial action in which the participant was instructed to focus on the context, resulted in greater movement than puckering, for which instructions focus attention on the movement of the lips. Facial impairment affected amplitude of movement, but blowing still produced greater amplitude of movement than puckering, even on the impaired side of the face. Duration was not longer for blowing on either impaired or unimpaired sides of the face, which indicated that people with facial impairment do not take longer to generate greater facial actions involving movements of the orbicularis oris muscle. Asymmetry was not different between puckering and blowing; the effects of facial impairment were likely to have been greater than any effects of context on asymmetry of facial movement.

Although physical therapy for facial nerve disorders is a common intervention, few controlled clinical trials have been carried out to determine effectiveness.[18] Various facial therapy regimens have included puckering movements aimed at improvement of the function for the orbicularis oris muscle. One study that did focus on the physical therapy treatment of Bell palsy showed a positive trend between physical therapy and facial function.[19] In total, 16 different facial actions were included in the exercise program. Ten of the 16 facial actions were designed to improve mouth movement.[19] Despite the number of facial actions in the study, it is unknown whether one facial action generates more effective movement than another.[19] The exercise regimen for the participants contained actions similar to the present study, including "pucker your mouth with closed lips (like "making a kiss"). This puckering action has a more practical context of instruction, differentiating the exercise from the typical instruction to "pucker your lips." Because of the context, the exercise could potentially impact facial movement, as was found for healthy participants given the instruction "blow, as if blowing out a candle" compared to pucker. Further investigation is necessary to determine the effectiveness of contextual and instructions-only approaches.

The results of the present study may be useful in physical therapy for people with facial nerve disorders. Therapists can work with people to construct a therapeutic regimen that includes facial actions with intent such as "blow, as if blowing out a candle." Puckering and blowing both use the same facial muscle, but directing people to focus on the context of instruction rather than just the movement may facilitate greater facial movement.

There was a positive relationship between maximum speed and amplitude of movement (correlations ranging from .645 to .760). The relationship was similar to that previously found and was similar on the impaired and unimpaired sides.[9] The similarity of values describing the strength of the relationship between maximum speed and amplitude for both movements suggested that underlying movement processes were similar in both puckering and blowing, although blowing produced a higher amplitude of movement. We concluded that the presence of impairment likely did not affect the relationship of speed and amplitude because relationships between these movement characteristics found in people with unilateral facial movement disorder were similar to those found in a previous study of healthy puckering and blowing movements.[9] It also is possible that using average values allows movement variation across points to obscure clear patterns of the relationship between amplitude and maximum speed.[9]

Because this study focused on 2 particular facial actions, further research is necessary to determine the extent to which the context of instruction influences facial movements. We speculate that differences in movement control when the goal of movement is accomplishing a well-learned task ("blowing out a candle") versus movement control when the goal is actually the movement itself ("puckering the lips") are responsible for the differences we observed. The pattern for a well-learned, externally directed task in which the goal is moving air may differ from the pattern for a well-learned, perhaps internally represented task for the goal of moving the lips. Recruitment of motor units for pucker may be more related to a central estimation based on past experience of recruitment of facial motor neurons for the pucker motion, while the blowing task may facilitate recruitment until the task is accomplished, focusing more on the goal of the present movement than a prior representation. In the presence of a unilateral facial movement disorder, recruitment based on past experience may be inadequate to generate the same amount or pattern of facial movement for the goal of pucker.

Clinically, a therapist cannot create a successful therapy regimen based on one facial movement. Although the results have important implications, instructions focused on tasks requiring lip movements to accomplish versus instructions focused on the lip movement is only one aspect of increasing total facial movements. Perhaps future studies could compare several facial actions with instructions to their nonspecific counterpart. "Pucker your lips, as if making a kiss" compared with "pucker your lips" would be an interesting comparison since the action and the muscle (eg, same muscle for puckering and blowing, orbicularis oris) involved are exactly the same, while only the context differs. Similarly, instructions to "smile as if happily greeting a favorite friend" compared with "smile," may be equally different with respect to tasks versus facial movement alone as the goal.

Conclusion

Studies similar to the present investigation may be helpful to determine whether context of instruction impacts movement performance of the entire hemisphere of the motor impairment associated with a facial nerve disorder, or only the movement problems associated with muscles of the lips. Such information may help physical therapists create therapeutic regimes involving facial actions that facilitate greater movement of the face. In conclusion, more effective physical therapy could lead to increased movement control and potentially lessen psychosocial distress of people with facial movement disorders.

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