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Measurement and analysis of associated mimic muscle movements

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Abstract

Objective: To measure movements of markers over the primary site and associated mimic muscles in certain facial expressions, for evaluating facial paresis and synkinesis. Methods: Participants included 22 normal subjects aged 45–66 years. Maximum shift (S_{max}) and velocity (V_{max}) were measured using a custom-designed 3-D dynamic quantitative analysis system of facial motion (3-D ASFM) based on motion capture technology. Measures were taken from peri-oral muscles during forceful brow raising and tight eye closure, and from muscles around the eye during grinning, right/left/bilateral mouth corner raising and smiling. Results: 1) During forceful brow raising, S_{max} was 3.65–4.46 mm for markers over perioral muscles, with the marker over the nasolabial fold showing a V_{max} greater than others (60.60 mm/s on left and 62.70 mm/s on right). 2) In tight eye closure, S_{max} of perioral muscle markers was 1.58–1.92 mm, with V_{max} being 11.40–14.76 mm/s. 3) In grinning, the largest eye muscle marker S_{max} was seen at the lower lid (3.93 mm on left and 4.15 mm on right) and the smallest at the inner canthus (1.59 mm on left and 1.53 mm on right), with the largest V_{max} seen at the upper lid and smallest also at the inner canthus (11.71 mm/s on left and 11.09 mm/s on right). 4) In smiling, the largest non-oral S_{max} and V_{max} were seen at the upper lid (3.05 mm and 36.14 mm/s on left and 2.53 mm and 28.90 mm/s on right) and the smallest also at the inner canthus (0.69 mm and 7.22 mm/s on left and 0.77 mm and 7.80 mm/s on right). 5) In right mouth corner raising, S_{max} and V_{max} at lateral and medial canthus and at lower lid were greater on right than left, while those at upper lid and brow were slightly greater on left than right. 6) In left mouth corner raising, S_{max} and V_{max} at lateral canthus and upper and lower lids were greater on left than right. Conclusions: There are no absolute immobile points on the face when making facial expressions. In addition to the primary movement site, there are associated movements at other points on the face with consistent S_{max} and V_{max}. In assessing facial paresis and synkinesis, physiological associated facial movements should be taken into consideration.

Keywords: Facial expression; Associated movement; 3-Dimensional measurement; Healthy volunteers; Facial nerve

1. Introduction

Facial expression is one of the basic modes of conveying emotional messages in human and forms the foundation of human social functionality. Facial paralysis is a common condition (Adour et al., 1978; Devriese et al., 1990) and results from facial nerve dysfunction, which leads to loss of facial muscle motor functions and synchronized facial movements. This is not only a loss of physiological function, but also affects the patient's psychological wellbeing and social activities. Treatments aim at restoring precise control of target facial muscles by the facial nerve, but about 12–29% of patients are left with some defects even after "effective" treatment, including synkinesis (Sullivan et al., 2007; Engstrom et al., 2008; Lockhart et al., 2010; Teixeira et al., 2010; Valenca et al., 2001).

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Synkinesis refers to abnormally associated movements, generally considered to be related to misalignment in facial nerve fiber regeneration or re-organization/excitability changes in facial nuclei or supra-nucleus centers. It is represented by involuntary movements triggered by voluntary contraction of the intended muscle, including upward mouth corner movement when closing eyes or eye closure when opening mouth. Synkinesis can significantly impact a patient's quality of life. However, even in healthy people, associated movements in various facial areas are frequently seen in facial expressions. Existing studies on facial movements mostly focus on planar measurements in areas around the primary movement, such as movements around the eye during eye-related facial expressions (Doughty, 2014; Frigerio et al., 2014; Nemoto et al., 1994; Jiang et al., 2013; Cook et al., 2003). The lack of three-dimensional measurement of associated movements in different facial areas hinders a comprehensive assessment of facial movement association. The current study aims to measure associated displacement of markers in areas different from the primary facial movement using a proprietary three-dimensional analysis system of facial motion (3-D ASFM) based on capturing facial movements (Feng et al., 2014), and to analyze relevant factors.

2. Materials and methods

2.1. Subjects

Twenty two healthy volunteers aged 46–60 years (mean = 54.4 years) participated in the study. They were all right-handed and presented no history of conditions that might affect mimic muscles functions. Consents were obtained before participating in the study.

2.2. Measurement of facial movements

The 3-D ASFM sampled at 60 frames/s. As reported previously, a total of 16 markers were placed symmetrically at the brow, upper and lower lids, medial and lateral canthus, nasolabial fold, middle point of lip and mouth corners (Fig. 1) (Feng et al., 2014). For forceful brow raising and tight eye closure that involved primarily muscles around the eye, the brow and upper lid markers were used as the reference points while the perioral markers were measured. Similarly, for facial movements involving mainly perioral muscles (grinning, forceful right or left mouth corner raising and smiling), the left and right mouth corners and upper and lower lip mid points were used as reference points while markers over muscles around the eye were measured.

The maximum shift (S_{max}) and maximum velocity (V_{max}) were used as the indices in measurement and analysis. S_{max} and V_{max} of various markers were recorded and plotted. The SAS 9.1.3 software was used for statistical analysis. Temporal synchronization among markers was assessed using repeat Chi square test (Chen, 2003) and $P < 0.05$ was considered to be statistically significant.

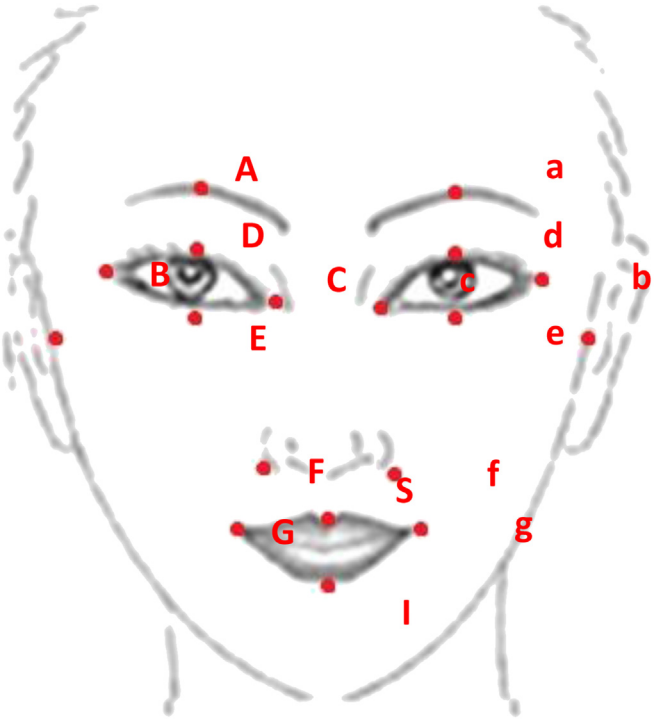

Fig. 1. Locations of the markers. A/a-eyebrow; B/b-lateral canthus; C/c-medial canthus; D/d-palpebra superior; E/e-palpebra inferior; F/f-nasolabial groove; G/g-modiolus; S-middle of the upperlip; I-middle of the underlip (With capitals showing the markers on the right side of the face and lowercases showing the markers on the left side.).

3. Results

3.1. Temporal synchronization

Tables 1 and 2 show the Chi square test results on temporal synchronization based on S_{max} and V_{max} of measured markers relative to reference markers during facial movements.

3.2. Forceful brow raising

S_{max} and V_{max} of the brow marker were 9.75 mm and 24.11 mm/s on left and 10.14 mm and 25.87 mm/s on right. For perioral markers, S_{max} ranged from 3.65 mm at the nasolabial fold to 4.46 mm at the lower lip. V_{max} of the nasolabial marker (60.60 mm/s on left and 62.70 mm/s on right) was greater than those of the other markers (ranging

Table 1
Temporal synchronization of S_{max} and V_{max} of measured markers relative to reference markers in forceful brow raising and tight eye closure (F value from Chi square test with P value in parenthesis, $\alpha = 0.05$).

Facial action	Forceful brow raising		Tight eye closure	
Parameter	S_{max}	V_{max}	S_{max}	V_{max}
Left brow	4.04(0.0527)	0.11(0.7433)		
Right brow	4.00(0.0538)	0.06(0.8006)		
Left upper lid			2.50(0.1232)	2.92(0.0969)
Right upper lid			2.44(0.1280)	2.92(0.0971)