

STIFFNESS OF THE HUMAN LIPS

Steven Barlow, Lana Seibel, Michael Hammer, Shiva Prasad & Megan Prather

¹ *Communication Neuroscience Laboratories
Department of Speech-Language-Hearing: Sciences and Disorders
3001 Dole Human Development Center
University of Kansas
Lawrence, Kansas 66045-7555*

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Contact Author:

Dr. Steven M. Barlow
Professor and Chair
University of Kansas
DOLE Human Development Center 3001
1000 Sunnyside Ave.
Lawrence, KS 66045-7555

sbarlow@ukans.edu

TEL: 785-864-0632

FAX: 785-864-3974

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A quantitative measure of perioral stiffness was developed and applied to healthy adult female subjects. Servo-controlled step displacements of the oral angle produced passive stiffness functions that were well characterized by a quadratic equation. This automated measure is considered a useful index to the clinical correlate of muscle rigidity.

Summary

One of the primary functions of skeletal muscle is to contract, thereby exerting a force against its local environment. In vertebrates, the maximum force a whole muscle can generate has been shown to be dependent upon muscle length (Bahler, Fales, & Zierler, 1968; Carlson, 1957; Fales & Zierler, 1969; Rack & Westbury, 1969). Using displacements imposed horizontally and tangential to the oral angle, Muller et al. (1985) recorded some of the first biomechanical data from perioral tissues in 4 adult subjects, including span-tension, and force-velocity relations over a displacement range of 20 millimeters. In another study, (Ho, Azar, Weinstein and Bowley, 1982) passive force at midline for the upper and lower lip was sampled in 20 adult Caucasian subjects (10 male, 10 female) using a strain gage force transducer. Each individual lower lip was found to be stiffer than the upper lip and the corresponding male lip is stiffer than the female lip for all spatial conformations of vermilion tissue displaced (from 0.6 to 1.6 cm²). Barlow & Muller (1991) elaborated previous findings and defined span-tension relations along the horizontal dimension including the characterization of active and passive force resulting principally from orbicularis oris and related connective tissues over a much larger range of interangle spans (25 to 70 millimeters). Both the active and passive components of interangle resultant force were found to be significantly related to interangle span over the range from 25 to 70 millimeters. The active interangle resultant force component of the MVC was significantly greater for male than female subjects, whereas passive forces were equal. This finding is consistent with the observation that males generate greater maximum midline closing forces of the upper and lower lips than females (Barlow & Rath, 1985). Differences in muscle bulk and mechanical advantage may account for the prominent gender difference on MVC measures. Recent anatomical and physiological evidence concerning the perioral musculature (Blair, 1986; Blair & Muller, 1984, 1987; Blair & Smith, 1986) has shown that the force plant capabilities of this system are affected by the complex interleaved architecture of fibers within the **OOm**, the architecture of the attachments of the muscle to other tissues, and the mechanical properties of surrounding tissues.

The results from these published works on perioral biomechanics point toward the need for clinical evaluations of muscle performance. In this vein, the objective of the current report is to detail a new computerized application for high-speed sampling and measurement of perioral stiffness using a servo-controlled linear motor. It is likely that passive and active components of span-tension functions for the oral angle will provide clinicians with a new non-invasive

predictive tool for assessing residual motor function in relation to perioral kinematics during nonspeech and speech motor activities.

Subjects and Test Methods

Thus far, 9 healthy adult females (age 21-33) served as experimental subjects. Each subject completed a written informed consent in compliance with the University of Kansas Human Subjects Internal Review Board. Subjects were seated in a dental examination chair with the head positioned comfortably against padded occipital cups. In the current study, subjects were instructed to look straight ahead and relax the facial muscles.

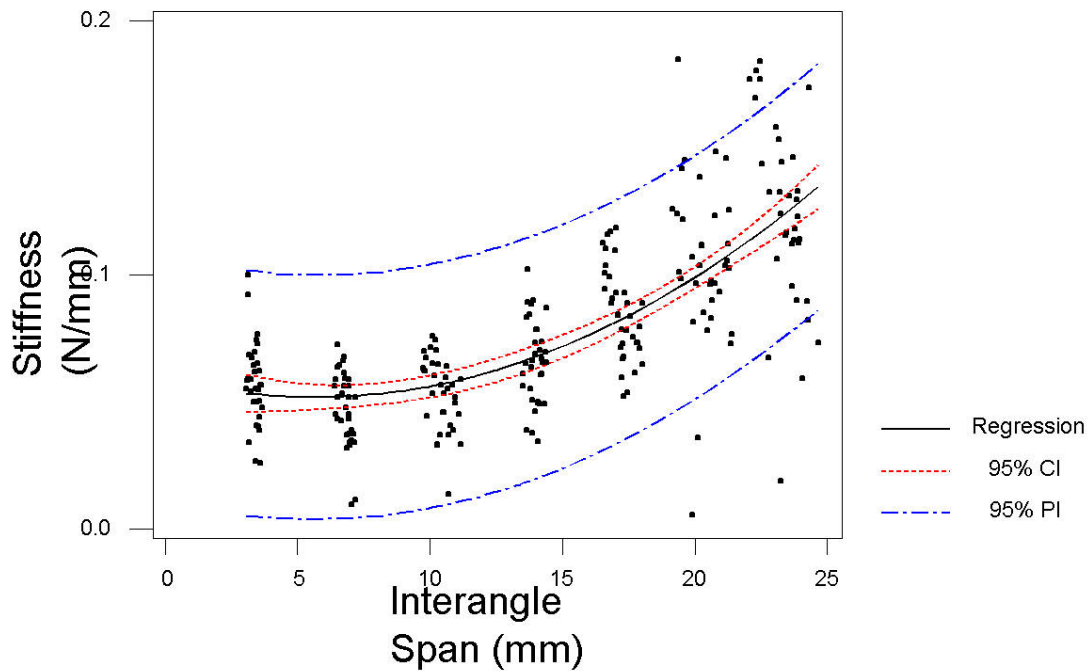
A custom designed linear servo motor, capable of 50 mm of translation and sampling 10 Newtons of force, was positioned to impose sequential ramp-step displacements at the right oral angle under position feedback. A stator hook referenced to the housing of the linear motor was positioned at the contralateral oral angle. The data acquisition microprocessor was programmed to generate an automated sequence of 8-step displacements at the oral angle. Each step was 3 millimeters and was sustained for 3 seconds before the 16-bit digital-to-analog converter produced the next step. The transition time between steps was 100 ms to reduce the possibility of evoking a stretch reflex. A single data block consisting of 8 imposed tangential displacements was completed in 27 seconds. Five data blocks were recorded for each subject. Motor input, load cell, and LVDT (displacement) signals were digitized at 100 samples/sec at 16-bits of vertical resolution. A software analysis program written in MATLAB v6.2 reduced the force and displacement signals to a series of passive stiffness coefficients plotted as a function of oral angle displacement and fit using nonlinear regression techniques.

Results

Quantitative measures of stiffness sampled at the oral angle were completed in approximately 3 minutes for each subject, including data acquisition and digital signal processing. For all healthy subjects tested thus far, a quadratic equation provided a statistically significant fit to the experimental data, and

NORMAL Pooled Interangle Stiffness

Stiffness (N = 0.0593752 - 0.0026314 Interangle S
 + 0.0002303 Interangle S**2
 S = 0.0242231 R-Sq = 53.0 % R-Sq(adj) = 52.6 %



The regression equation is:

$$\text{Stiffness (N/mm)} = 0.0593752 - 0.0026314 \text{ Interangle Span} + 0.0002303 \text{ Interangle Span}^2$$

S = 0.0242231 R-Sq = 53.0 % R-Sq(adj) = 52.6 %

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	0.160126	0.0800628	136.45	0.000
Error	242	0.141995	0.0005868		
Total	244	0.302121			

Source	DF	SS	F	P
Linear	1	0.140447	211.094	0.000
Quadratic	1	0.019679	33.538	0.000

Preliminary application of the perioral stiffness protocol detailed in the present report to individuals with various forms of progressive neuromotor disease (i.e., Parkinson's disease) and acquired insults to the nervous system (stroke, traumatic brain injury) should prove useful clinically to determine the effects of medication, neurosurgical therapies (posteroventral pallidotomy, subthalamic nucleus deep brain stimulation). Given the positive relation between increases in muscle rigidity (stiffness) and speech kinematics, it becomes increasingly important to manage neuromotor disturbances that affect the resting stiffness of muscle.

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