Muscle Tone and the SLP: Definitions, Neurophysiology, Assessment, and Interventions

Heather M. Clark, Ph.D., CCC-SLP
Fellow
Department of Neurology
Mayo Clinic, Rochester MN

Nancy Pearl Solomon, Ph.D., CCC-SLP
Research Speech-Language Pathologist
Walter Reed Army Medical Center, Washington DC

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The Role of the SLP
- Oral-Motor Assessment
  - Strength
  - Endurance
  - Range of motion
  - Coordination
- Oral-Motor Treatment
  - Targets same areas

Outline
Part 1: Foundations
- Literature review
  - Current concepts of muscle tone and the role of the muscle spindle
  - Muscle tone impairments associated with neuropathology
- Applications by other disciplines
  - Assessment of muscle tone for limbs and torso
  - Therapeutic interventions involving sensory and motor techniques

Outline
Part 2: SLP Applications
- Assessment of orofacial muscle tone
  - Unique anatomical and physiological features of orofacial muscles
  - Evidence of tone impairments underlying dysarthria and dysphagia
  - Measurement procedures
- Therapeutic interventions: preliminary results
  - Sensory: icing and vibration
  - Motor: strengthening exercises

Why Not Muscle Tone?
- Presumed to be important for normal and disordered neuromuscular function
- Abnormal muscle tone is presumed to be associated with specific neuropathologies of speech and swallowing
- Assessment procedures/tools are unavailable
- Interventions targeting muscle tone are often recommended to improve speech and swallowing but lack evidence

Muscle Tone Defined
- Resistance of a resting muscle to passive stretch
- Influenced by tissue elasticity and resting motor unit activity
Muscle Tone Regulation

- Peripheral Reflexes
  - Stretch (muscle spindles)

- Descending pathways
  - Indirect upper motor neuron pathways
  - Basal ganglia control circuit
  - Cerebellar control circuit

Stretch Reflex

- Receptor: Muscle spindle
- Stimulus: Change in muscle length

- Afferent: Ia
- Efferent: α
- Effects
  - on agonist: Mono (and poly-) synaptic excitation
  - on antagonist: Disynaptic inhibition
- Result: contraction

Prototypical Stretch Reflex

- Rapid lengthening of muscle spindle causes discharge of Ia afferents
- These synapse directly with α motor neurons
- Collaterals of Ia synapse on inhibitory Iα interneurons that inhibit α motor neurons of the antagonist
- GABA

Central Regulation of the Stretch Reflex

- Indirect upper motor neuron pathway
  - Descending neural drive has an overall inhibitory effect on reflexes
  - Removal of this influence leads to hyperreflexia (increased excitability of gamma motor neurons)

Central Regulation of the Stretch Reflex

- Basal Ganglia Control Circuit
  - Inhibitory effect on the motor thalamus
  - If damage leads to reduced thalamic inhibition, then cortical excitation is abnormally heightened

Rubchinsky et al., 2003; http://www.ncbi.nlm.nih.gov/pmc/articles/PMC283608/figure/fig1/
Central Regulation of the Stretch Reflex

- Cerebellar Control Circuit
  - Thought to affect tonicity, such that damage leads to hypotonia
  - Most relevant in children
  - Mechanism not understood

Tone Impairments

- Hypotonia
  - Flaccid: diminished signals in reflex arc
  - Cerebellar: increased inhibition from descending indirect pathway onto lower motor neuron pools

- Hypertonia
  - Spastic: released inhibition from descending indirect pathway onto gamma motor neurons
  - Rigid: increased excitability of α motor neurons

Variable Tone

Tone Impairments in Neurologic Disease

- Developmental
  - Cerebral Palsy
    - Hypotonia: ataxic
    - Hypertonia: spastic, hyperkinetic
  - Down Syndrome
    - Flaccid
  - Moebius Syndrome
    - Flaccid

- Acquired
  - Parkinson Disease: rigid
  - Stroke
    - Cerebral: spastic
    - Subcortical: spastic or flaccid
    - Cerebellar: hypotonia
  - MS: spastic, ataxic
  - ALS: spastic, flaccid
  - Hyperkinesias: dystonia

Assessment of Muscle Tone

- Clinical
  - Passive displacement of relaxed limb
  - Modified Ashworth Scale (6-point scale)
  - Position limb passively and release
    - Observe if position is maintained
  - Muscle palpation
    - Feel for resistance to tissue deformation
  - Pendulum swing
    - Lift limb and release
    - Observe free swinging of limb

- Instrumental
  - Torque motor
    - Resistance to rotation around a joint
  - Electromyography
    - Muscle activity: agonist-antagonist
  - Myotonometer
    - Resistance to deformation
  - Myoton
    - Damped oscillation to tissue perturbation

Management of Tone Impairments

- Pharmacologic
  - Muscle relaxants
    - (e.g., Baclofen)
  - Muscle paralytics
    - (e.g., botulinum toxin)

- Surgical
  - Spasticity
    - Tendon lengthening
    - Rhizotomy
  - Rigidity
    - Pallidotomy
    - Deep brain stimulation
Behavioral Interventions for Tone

- Intended to affect muscle spindle
  - Stretching
  - Vibration
  - Tapping

- Intended to affect nerve/muscle function
  - Icing
  - Massage

Passive Stretching

- Fast
  - Stimulates stretch reflex
  - Increases tone

- Slow
  - Inhibits stretch reflex
  - Decreases tone

- Evidence
  - Moderate to strong evidence that stretching does not affect spasticity in limb (Cochrane review)

Vibration

- Stimulates muscle spindle
  - Increases tone of stimulated muscle
  - Decreases tone of antagonist

- Evidence
  - Improves head/neck alignment (Canon et al 1987)
  - Improves spasticity (Noma et al 2009)

Tapping

- Stimulates muscle spindle
  - Increases tone

- Evidence appears to be lacking

Icing

- Decreases nerve conduction velocities
- Decreases muscle contraction speed and extent

- Evidence
  - Numerous studies in PMR literature addressing various muscle groups
  - Improved jaw opening in children with spastic CP (dos Santos & de Oliveira, 2004)

SUMMARY

Part 1: Foundations

- Muscle tone is mediated by stretch reflex
- Stretch reflex is affected by
  - Muscle spindle function
  - Central nervous system regulation

Therapeutic interventions

- Aim to alter responsiveness of muscle spindle or other components of the stretch reflex
- Evidence for benefit in general skeletal muscles varies
Part 2: SLP Applications

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  - Sensory: icing and vibration
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Muscle Spindle Action in Speech/Swallowing Muscles

- Jaw closing muscles
  - High density muscle spindles
  - Strong stretch reflex
- Face & lips
  - Low density or lack of muscle spindles
  - Do not exhibit stretch reflexes

Muscle Spindle Action in Speech/Swallowing Muscles

- Tongue & palate
  - Muscle spindle density similar to limbs
  - Do not exhibit typical stretch reflexes (Neilson et al., 1979)
- Pharynx, larynx
  - Presence of muscle spindles varies across muscles
  - No studies to date have demonstrated stretch reflexes in the human larynx (Ludlow, 2005) or pharynx

Assessment of Orofacial Muscle Tone

- Clinical
  - Stretch
  - Palpation
- Instrumental
  - OroSTIFF (only one designed for orofacial use)
  - Myotonometer
  - Myoton

Clinical Assessment of Muscle Tone

- Resistance to passive stretch or displacement
  - Externally applied stretch, usually across a joint
- Resistance to deformation
  - Palpation of relaxed muscles
- Orofacial tone assessments
  - Dworkin & Culatta (1996)
  - Beckman (1988)

Instrumental Tools

- Measure tissue response to perturbation
  - Resistance to passive stretch
  - Resistance to tissue deformation/palpation
OroSTIFF

(Chu, Barlow, Kieweg, & Lee, 2010)

Myotonometer

- Measures deformation and force
- Calculates tissue compliance

Myoton

- Parameters
  - Frequency of oscillation
  - Damping coefficient
  - Stiffness

Veldi et al. (2002)

- Application for sleep apnea
- Assess tone of tongue and velum

Evidence for Tone Impairments in Dysarthria and Dysphagia

Presumed (Darley, Aronson & Brown, 1969)
- Flaccid: hypotonia
- Spastic: spasticity
- Hypokinetic: rigidity
- Ataxic: normal
- Hyperkinetic: mixed

Data
- Flaccid: hypotonia
- Spastic: No hyperactive stretch reflexes in the tongue in spastic dysarthria (Nielsen, et al 1979)
- Hypokinetic: Increased lip stiffness (Hunker, Abbs, & Barlow, 1982; Chu et al., 2010)
- Ataxic: none
- Hyperkinetic: none

Stiffness of tongue and cheeks

- Are measures of tissue stiffness obtainable and repeatable from the tongue and cheeks of neurologically normal individuals?
- Do tongue and cheek stiffness differ between persons with LMN, UMN and no neurologic lesions?
- Does stiffness of the right and left sides differ in persons with unilateral neurologic deficits?
  - Lower with LMN impairment
  - Higher with UMN impairment

(Solomon & Clark, 2010)
Method

Participants
- 9 neurologically normal adults
- 13 neurologically impaired adults

Summary: Tongue & Cheek Stiffness
- Normal and disordered participants tolerated the Myoton measurement procedures well
- Tongue stiffness was generally lower in the LMN group than in the normal group
- Very preliminary
  - Interpret with extreme caution!!

Interventions for Orofacial Muscle Tone

Sensory
- Applied by clinician
- Target sensory endings or afferent pathways of reflex loops

Motor
- Performed by patient
- Target efferent pathways or muscle function

Slow Stretch

Peripheral targets
- Inhibits stretch reflex to reduce tone and increase ROM (applicable only for jaw)

Central targets
- Calming effect (addresses hyperresponsivity)

Quick Stretch & Tapping

Peripheral targets
- Intended to increase tone by stimulating the stretch reflex
- Would expect greatest effects in jaw-closing musculature

Central targets
- Alerting effect (addresses hyporesponsivity)
- Stimulate proprioceptive pathways (be aware of interference issue)
Massage

- Peripheral Targets
  - Superficial and deep cutaneous receptors
  - Intended to decrease tone and/or muscular hyperfunction
- Central Targets
  - Speed and/or intensity of massage determines whether effects are calming or alerting

Vibration

- Peripheral Targets
  - Elicits tonic/tendon vibratory reflex (TVR)
    - Acts on the muscle spindle
    - Increases tone of agonist
    - Decreases tone of antagonist via reciprocal inhibition
    - Would be expected to only influence jaw-closing muscles
- Central Targets
  - Speed and/or intensity of vibration determines whether effects are calming or alerting
  - Purported to have calming or alerting effects, depending on the child
  - Activate proprioception pathways (interference effects)
- Additional Issues
  - Prolonged vibration may cause tissue breakdown
  - May exacerbate extrapyramidal symptoms

Cold

- Peripheral Targets
  - Decreases tone by decreasing nerve conduction velocities
  - May heighten sensitivity of cutaneous receptors
- Central Targets
  - Generally has an alerting effect

Sensory intervention on orofacial muscle tone: Preliminary study

- Submental Tissue
  - Vibration
  - Icing

Method

- Participants
  - 16 women
  - Neurologically normal
- Tissue compliance measures
  - Tested on 2 days
  - Before and after
    - Icing
    - Vibration
Submental Compliance Before & After Sensory Intervention

Summary:
Submental compliance

- Submental tissue compliance decreased (stiffness increased) after icing but not vibration
- Increased tissue stiffness after icing could derive from
  - Stiffening of non-muscular and muscle tissue
  - Changes in blood flow
  - Increased muscular activity

Motor Intervention

- No evidence for swallowing or speech
- Limited indirect evidence from obstructive sleep apnea syndrome (OSAS) literature
  - Guimaraes et al. (2009)
    - 31 adults with obstructive sleep apnea syndrome
    - 3 month program of oropharyngeal exercises
    - Improved snoring frequency and intensity, daytime sleepiness, sleep quality, and overall severity
  - Puhan et al. (2005)

Didgeridoo playing reduces snoring

- 25 adults with OSAS
  - 14 practiced ~25 min, 6 days per week, 4 months
  - 11 controls
  - Improved
    - Daytime sleepiness (Epworth scale)
    - Partner rating of sleep disturbance
    - Apnoea-hypopnoea index

Case Study

- 42 y.o. male
- Multiple injuries
- 2 mo post blast injury
  - Evaluation
    - Strength (QIP)
    - Tone (Myoton)
- 4 mo post
  - Tongue exercises
    - 40 trails
    - 4x/day
    - 5 days/wk
  - 5 mo post
    - Add cheek exercises
  - 6 mo post
    - Discharge

SUMMARY
Part 2: SLP Applications

- Orofacial muscle tone is rarely assessed by the SLP, and is almost never quantified
- Certain instruments may become available to determine orofacial tissue stiffness
- Therapeutic interventions intended to normalize tone may be applied to the orofacial muscles, but no evidence exists
- Very new and very preliminary evidence indicates that
  - Tissue compliance can be assessed for the lingual, facial, and submental muscles
  - Icing may increase submental tissue tone
  - Tongue strengthening exercise increases strength but may or may not increase tone
- Much more work needs to be done to address these issues
References