Sensorimotor Interventions: Science, Application, and Evidence
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Defining Oral Motor Exercise
Nonspeech activities that involve sensory stimulation to or actions of the lips, jaw, tongue, soft palate, larynx, and respiratory muscles which are intended to influence the physiologic underpinnings of the oropharyngeal mechanism and thus improve its functions.
ASHA National Center for Evidence Based Practice Panel on OMT

Review of Somatosensory Afferents

- Discriminative touch
- Proprioception
- Taste
- Pain & Temperature

Discriminative Touch

- Face, lips, mouth (including anterior tongue) – CN V
- Posterior Tongue – CN IX
- Pharynx & Larynx – CN X (Pharyngeal and Superior Branches)

Afferent Pathways

- Many fibers from NTS project directly to NA motor nucleus

Afferent Pathways

- Remaining fibers from NTS and Trigeminal Nucleus travel in the medial lemniscus to VPM (ventromedial posterior nucleus) in thalamus
Afferent Pathways
Continue in thalamo-cortical tract to somatosensory cortex

Discriminative Touch
- Role in Speech
  - Contact with articulators and environment
  - Changes in air pressure
  - Deformations in skin and mucosa
- Role in Swallowing
  - Direction of load applied to teeth
  - Bolus control and manipulation
  - Trigger pharyngeal response
  - Signal bolus characteristics

Proprioception
- Muscles of Mastication
  - Muscle spindle afferents have cell bodies in the mesencephalic nucleus
  - Most of these afferents synapse directly on motor nucleus of CN V (stretch reflex circuit)
  - Experimental evidence suggests that muscle spindles in the masseter signal jaw position and movement

Proprioception
- Lips & Face
  - Cutaneous receptors with CN V afferents are sensitive to stretch and deformations in skin related to muscle contraction
  - Some of these fibers have interneuron connections with CN VII motor nucleus (peri-oral reflex)

Proprioception
- Tongue
  - Muscle spindle afferents (coursing in CN V, IX, or XII) may have some monosynaptic reflexes
  - Cutaneous afferents (CN V) are also thought to signal movement information

Proprioception
- Pharynx, Larynx
  - Muscle spindle, joint receptor, and mucosal afferents for CN X project to NTS
  - Relatively direct synapses with NA are presumed due to short latency reflexes
Afferent Pathways*

- Proprioceptive afferents synapse on reticular formation
- Course
  - Via reticulocerebellar tract to ipsilateral cerebellar cortex
  - Via spinothalamic tract to VPM and on to contralateral somatosensory cortex

* Reports disagree regarding the nature of unique proprioceptive paths

Proprioception

- Role in Speech
  - Deformations in skin and mucosa and muscle spindle afferents provide feedback related to movement
- Role in Swallowing
  - Stretch reflex in jaw closing muscles contributes to closed mouth posture
  - Muscle spindle afferents may contribute to modifications to pharyngeal response

Taste

- Anterior tongue: via chorda tympani to geniculate ganglion (CN VII), synapse on NTS
- Posterior tongue, epiglottis: CN IX and CN X synapse on NTS

Afferent Pathways

- Secondary afferents project from NTS to
  - NA
  - Pontine taste area to
    - Diencephalon (amygdala, hypothalamus and VPM) to
    - Somatosensory cortex

Taste

- Role in Swallowing
  - Bolus awareness
  - May influence timing and intensity of pharyngeal response

Pain & Temperature

- Cranial Nerves
  - Face, lips, mouth (including anterior tongue) CN V
  - Posterior Tongue – CN IX
  - Pharynx & Larynx – CN X (Pharyngeal and Superior Branches)
- Afferent Pathways
  - Many fibers NTS -> NA motor nucleus
  - Remaining fibers in NTS and Trigeminal Nucleus travel in the spinothalamic tract to VPM in thalamus
  - Thalamocortical tract to somatosensory cortex
Temperature

• Role in Speech?
• Role in Swallowing
  – Bolus awareness
  – May influence timing of pharyngeal response

Central Projections

• Somatosensory Afferents May Influence Motor Control via
  – Association fibers connecting sensory and motor cortices
  – Cerebellar projections to motor cortex
  – Extrapyramidal connections through reticular formation

Somatosensory Contributions to Speech Motor Control

• Somatosensory information relevant to speech control
  – Muscle spindle (articulator position, muscle length & contraction velocity)
  – Cutaneous afferents
    • Response types: Slow and Fast adapting
    • Stimuli types
      – Contact with articulators and environment
      – Changes in air pressure
      – Deformations in skin and mucosa
      – Direction of load applied to teeth

Somatosensory Contributions to Speech Motor Control

• "Speakers want to get the movements right, independent of the acoustics"
  Nasir & Ostry (2006)

Somatosensory Contributions to Speech Motor Control

• Basic perturbation experiment
  – Subject produces movements
  – At a key point in the movement trajectory, a mechanical load is applied to the articulator “perturbing” the movement

Somatosensory Contributions to Speech Motor Control

• Tremblay, Shiller, & Ostry (2003)
  – Tailored mechanical load such that perturbations resulted in no detectable alteration in perceptual accuracy or acoustic outcome
  – Applied perturbation during
    • Normal speech
    • Silent speech
    • Nonspeech movements that match speech with respect to amplitude and duration of movements
Somatosensory Contributions to Speech Motor Control

- Load initially turned on
- After period of adaptation
- Load unexpectedly removed

Somatosensory Contributions to Speech Motor Control

- “Adaptation is observed only when the movements are related to speech, even though movements in speech and non-speech conditions have the same dynamics”

Load initially turned on, After period of adaptation, Load unexpectedly removed

Key Peripheral Connections

- NTS
  - Touch V, IX, X
  - Proprioception X
  - Taste VII, IX, X
  - Pain & Temperature V, IX, X
- NA
  - Motor efferents IX, X

Sensory Stimulation Sites that Induce Pharyngeal Swallow (Perlman & Schulze-Delrio, 1997)

- X - Superior Laryngeal Nerve (pharynx, larynx)
  - Most effective site
- IX - Glosso-pharyngeal Nerve (posterior tongue, velum)
  - Higher threshold than SLN
- V - Trigeminal Nerve (oral mucosa, teeth)
  - Proprioceptive inputs from muscles of mastication thought to influence swallow initiation
Sensory Characteristics that Induce Pharyngeal Swallow

- Mechanical
  - Light pressure to anterior pillars (IX)
  - Heavy pressure to posterior pharyngeal wall (X)
  - Dynamic pressure more effective than static pressure
- Chemical/Taste
  - Fluids in laryngeal region (X)
- Thermal inputs
  - Most effective regions are unknown although receptors appear more dense on face and anterior regions of mouth (V)

When will sensory input trigger the pharyngeal swallow?

- Stimulus must activate fibers that synapse within the NTS and surrounding reticular formation
  - Dynamic stimulation
  - CN X

Additional Sensory Influences on Swallowing Function

- Bolus characteristics may alter the timing and amplitude of muscle activity
  - Volume
  - Viscosity
  - Taste
- Sensory stimulation may alter the threshold for initiation of the pharyngeal swallow (facilitate or inhibit)

Assessment of Sensation

- Standard cranial nerve assessment
- Single point threshold
  - Von Frey Hairs
  - Vibration
- Two-point discrimination
- Directional sensitivity
- Oral stereognosis

Assessment Programs

- Beckman
  - Emphasizes tissue/motor response to sensory stimulation
Assessment Issues

• What is the normal range of somatosensory function?
  – Research literature includes reports of thresholds for tongue, but methods vary and n’s are low
  – Hollingsworth et al (2007) examined relationships among lingual sensory measures in patients referred for swallowing evaluations, but did not report thresholds

Sensory Assessment - Conclusions

• Few clinical tools exist to assist in assessing aspects of somatosensory function thought to influence speech and swallowing function
• As clinical tools are developed, normative data will enhance clinicians’ ability to identify abnormal somatosensory function

Sensory Disruption in Speech & Swallowing Disorders

Parkinson Disease

• Individuals with PD may be impaired in their ability to judge movement amplitudes based on kinesthetic information (Kent et al, 2000)
• Evidence of impairments in temporal discrimination (Artieda et al, 1992) and orofacial kinetic sensitivity (Schaider et al, 1986)

Cerebellar Disease

• Sensory ataxia results from lack of proprioceptive input resulting from peripheral sensory neuropathies
• Cerebellar disease results in impaired ability to provide internal state estimation and sensory prediction (Mall, 1998)
• Impaired internal model of the musculoskeletal system (Ito, 1999)

Flaccid Dysarthria

• Damage to cranial nerves and/or brainstem nuclei resulting in flaccid dysarthria may also result in sensory deficits
• The nature and/or impact of peripheral sensory loss on speech/swallowing has not been well described
Apraxia of Speech

- Rosenbek, Wertz & Darley (1973)
  - Patients with aphasia and apraxia of speech impaired in their ability to
    - Identify geometric forms placed in the mouth (oral stereognosis)
    - Discriminate two-point stimulation
    - Compare degree of jaw opening to a reference
  - Degree of impairment positively correlated with severity of speech deficit

Stuttering

- Early reports suggested a deficit but these findings were not replicated in later studies

Popular Conceptions

- Boshart (1998) states that tactile information is the most critical sensation in speech production
- Many oral-motor advocates contend that children with speech and/or feeding difficulties often exhibit somatosensory deficits in the form of
  - Reduced sensitivity (hyporesponsivity, hyporeaction, sensory dormancy)
  - Exaggerated sensitivity (hyperresponsivity, hyperreaction, sensory overload)
  - Sensory defensiveness
  - Impaired sensory integration
  (Boshart, 1998; Chapman-Bahr, 2001; Morris & Klein, 2000; Rosenfeld-Johnson, 2001)

Sensory Deficits and Speech-Swallowing Function

Summary

- Anecdotal reports suggest that somatosensory deficits are common in individuals with speech and swallowing disorders
- A small number of reports describe somatosensory deficits in specific acquired conditions
- Additional research is needed to characterize the nature and impact of somatosensory deficits accompanying speech and swallowing disorders

Disrupted Tone

- Tone
  - Resistance to passive stretch
  - Influenced by CNS & PNS
    - Stretch reflex
    - Tonic regulation by extrapyramidal system and basal ganglia control circuits

Disrupted Tone

- Hypotonia
  - Reduced tone
  - Usually associated with PNS lesion (flaccid dysarthria)
- Hypertonia
  - Increased tone
  - Associated with CNS lesion
    - UMN (spastic dysarthria)
    - Control Circuit (hypokinetic dysarthria)
Assessing Tone

• Issues
  – Tone of individual muscles may be difficult to ascertain because of overlap in structure and function
  – Impairments in tone may not be manifest in the same way in the muscles innervated by cranial nerves as observed in limbs

Assessing Tone

• Subjective
  – Judge resistance to passive stretch
  – Appearance
    • Facial droop
    • Lip retraction

  • Objective
    – Measure resistance to stretch or muscle deformation

Peripheral Muscle Groups

D-Come

– “Use gloved fingers of both hands to pull down the patient’s lower lip toward the chin (at least three times) to appraise muscle tone/elasticity”
– “Hold gauze between the thumb and index finger of both hands and then grasp and gently pull the tongue-tip in various directions: forward, right and left, and up and own, at least three each direction”

Objective Tone Measures

• Myotonometer
  – Measures muscle tissue compliance

D-COME Cont

• Rating Scale
  – 1. Normal (passive) resistance
  – 2. Hypotonic (flaccidity) resistance
  – 3. Hypertonic (rigidity) resistance

• No norms exist regarding “normal” amount of resistance
• Does not rate tone of jaw, articulator most likely to exhibit hypertonicity

Myoton
Linear Servo Motor
(Siebel & Barlow, 2007)

Proximal Muscle Groups
Velum and pharynx
– Slow, symmetrical movements may indicate hypertonia
– Droop, often asymmetrical, may indicate hypotonia
• Larynx
– Hypertonicity typically has bias for hyperadduction (strained, strangled vocal quality)

How does tone relate to speech/swallowing function?
• Neilson et al (1979)
  – Participants who stuttered or exhibited spastic dysarthria exhibited no evidence of hyperactive stretch reflexes (spasticity)

Targets of Sensory Stimulation
• Peripheral pathways
  – Including brainstem reflexes (muscle tone)
• Central pathways

Peripheral Pathways
• Targets
  – Muscle spindles reflexes
  – Cutaneous reflexes
  – Swallowing reflexes

Muscle Spindle Reflexes
• Stimulation of muscle spindle elicits stretch reflex
  – Involuntary contraction of agonist
  – Inhibition of antagonist
• Resulting contraction may be large (knee jerk) or small (<10% muscle activation of voluntary contraction)
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

• 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

Cutaneous Reflexes

• Perioral Reflex
  – Short latency reflex elicited by mechanical stimulation to perioral tissue
  – Pathway involves cutaneous mechanoreceptors, maxillary trigeminal nerve fibers via interneurons to facial nerve efferents
  – Amplitude of EMG response is quite small

Swallowing Reflexes

• Order of effectiveness in eliciting swallow reflex
  – Superior Laryngeal Nerve is most effective
    • Mechanical
    • Taste
    • Thermal inputs
  – Glossopharyngeal
  – Trigeminal
    • Lingual nerve stimulation may inhibit swallowing reflex

Central Pathways

• Awareness/Alertness
• Acceptance
• Proprioception / Motor control
  – Task Specificity
  – Motor Learning Principles
    • Somatosensory information regarding initial conditions and kinesthetic/proprioceptive consequences of the movement contributes to schema development and motor learning

Sensory Stimulation Methods

• Most common somatosensory stimulation strategies (often combined in specific techniques or programs)
  – Stretch
  – Tapping
  – Vibration
  – Massage
  – Heat
  – Cold
  – Gustatory
  – Proprioceptive
  – Transcutaneous Nerve Stimulation
  – Appliances
**Slow Stretch**

- Peripheral targets
  - Inhibits stretch reflex to 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

**Beckman**

- Specifically: passive stretches of lips, cheeks, & nasal bridge
- Reported purpose: to increase strength and ROM, “normalize patterns”
- Analysis
  - Not likely to affect strength or hypotonia
  - Questionable effect on hypertonia
  - Sensory stimulation to cutaneous afferents may target alertness, peri-oral reflex

**Hall (2001) Pediatric Dysphagia Resource Guide Table 4 -1 & 4 -3**

<table>
<thead>
<tr>
<th>Technique</th>
<th>Reported Purpose</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheek Tapping</td>
<td>Increase tone</td>
<td>No muscle spindles</td>
</tr>
<tr>
<td>Jaw Tapping</td>
<td>Increase tone</td>
<td>Should work</td>
</tr>
<tr>
<td>Quick Stretch</td>
<td>Improve tone</td>
<td>No muscle spindles</td>
</tr>
<tr>
<td>Cheek Massage</td>
<td>Increase tone</td>
<td>Massage reduces tone</td>
</tr>
<tr>
<td>Lingual Stroking</td>
<td>Increase strength</td>
<td>Massage does not affect strength</td>
</tr>
</tbody>
</table>

**Vibration**

- Peripheral Targets
  - Phasic stimulation may enhance response of fast adapting receptors
  - More likely to elicit swallow reflex
  - 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
Vibration

- Central Targets
  - 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

Hall (2001) Pediatric Dysphagia Resource Guide Table 4-1 & 4-3

- Cheek/lip vibration to improve tone
  - No muscle spindles

Heat

- Peripheral Target
  - Elevates threshold for pain
  - Allows for increased ROM by inhibiting pain-induced muscle spasm
- Central Target
  - Generally thought to have calming effects unless patient has specific aversion to heat

Cold

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

Gustatory Stimulation

- Peripheral Targets
  - Swallow reflexes
  - Sour increases amplitude of genioglossus activity
- Central Targets
  - Bolus awareness and acceptance (alerting)
  - Pleasure

Proprioception

- Activities include eliciting active and passive movements to stimulate proprioceptive afferents
  - Example: using a bite block to enhance pressure feedback to heighten awareness and maximize feedback (Morris & Klein, 2000)
  - Vibration to masseter to stimulate proprioception pathways
  - Physiology research predicts that processing of proprioceptive information is task specific
- Deep pressure and whole body proprioceptive activities are thought to be calming
Transcutaneous Electrical Nerve Stimulation (TENS)

- Electrical currents used to stimulate nerves through the skin
- Intended to relieve pain, current is too low to induce muscle contractions
- Safety precautions
  - Do not use near eyes
  - Do not use in the mouth
  - Contra-indicated in trigeminal neuralgia

**Appliances**

ISMAR: Innsbruck
Sensorimotor Activator and Regulator

- Variations in the surface stimulate oral movements
- Shelves provide jaw stability
- Oral shield limits lingual protrusion
- Recommended for secretion management & tongue thrust

Somatosensory Treatment

What evidence exists that treatments targeting somatosensory function improve speech and/or swallowing?

ASHA National Center for Evidence Based Practice

- ASHA staff in collaboration with an expert panel
- Identify and review peer-reviewed literature for quality of evidence addressing specific clinical questions
- Disseminate findings at conventions and through ASHA publications

Oral Motor Systematic Review

- What is the effectiveness of OME on
  - sensorimotor function and structure?
  - swallowing physiology?
  - pulmonary health?
  - functional swallowing outcomes?
  - drooling / secretion management?
  - neurologic activation during swallowing?

Oral Motor Systematic Review

- What is the effectiveness of OME on
  - speech physiology?
  - sound production?
  - functional speech outcomes?
  - neurologic activation during speech?
Oral Motor Systematic Review

- Nearly 900 articles considered for review
- 96 included in final review
- Quality indicators
  - Study design
  - Participant descriptions
  - Intervention descriptions
  - Outcomes and significance
- Preliminary findings reported at ASHA

Classified into Research Stage

- Efficacy Studies
  - Experimental design
  - Disordered population
  - Treatment study
- Exploratory Studies
  - Any study not meeting criteria for efficacy – non-experimental designs, healthy subjects, condition study,

Oral Stimulation & NNS

- Neonates
  - Efficacy (1 study)
    - Oral stimulation improved measures of sucking and feeding (single subject design N=3)
  - Exploratory (1 study)
    - Oral simulation improved feeding physiology and resulted in increased oral intake (case series N=29)

Oral Stimulation

- Children
  - Efficacy (2 studies)
    - Reduced tongue thrust (SSD, N=1 child with CP)
    - Improved lip seal and chewing (SSD, N=4 children with severe multiple handicaps)

Appliances

- Efficacy: 3 studies (dysarthria)
  - Oral stimulating plates for up to 4 years improved lip rounding but not perceptual accuracy of articulation or intelligibility
- Exploratory (1 study)
  - Use of an oral appliance improved feeding skills and reduced drooling (case series, N=18)

Thermal-Tactile Stimulation

- Adults
  - Efficacy (1 study)
    - TTS + oral stim + oral massage + digital manipulation improved swallowing physiology (but not occurrence of pneumonia or LOS)
  - Exploratory
    - 4 studies with normal subjects during a single session
      • 2 showed no effect
      • 1 showed shorter latency with cold+tactile+sour
      • 1 showed “brisk” response
    - 2 studies with patient groups during a single testing session
      • Reduced stage transition time (stroke pts)
      • No effect (neurologic pts with delayed swallow response)
TENS

- Exploratory studies
  - Applied electrical current to faucial pillars
  - No effect on patient swallowing function
  - Healthy participants experienced lengthened response times

Lower Level Evidence

- Beckman
  - Unpublished report describing improved strength and ROM of lips and cheeks as a result of somatosensory stimulation techniques (uncontrolled study)
- Vibrotactile cues
  - In addition to auditory cues improved single word production by a patient with apraxia of speech more effectively than auditory cues alone (Rubow, et al., 1982)
- Sour bolus
  - Improved swallowing onset (Logemann 1995)
  - Reduced penetration/aspiration (Pelletier & Lawless, 2003)
  - Small amounts generally found to be more effective than large amounts

Orofacial Vibration
(Taylor, Anderson & Pail-Hoffman, 2004)

- Vibration applied to specific landmarks
  - Facial muscle landmarks
  - Tongue tip and tongue blade
  - Hard palate
- Reported outcomes
  - Recovery of reflexes
    - Protective reflexes in adult dysphagia
  - Enhanced alertness & attention
- Cautions
  - Neurophysiologic mechanism unidentified
  - Tactile defensiveness
  - Avoid stimulation greater than 7 seconds

Clark & Solomon

Evidence: Summary

- Swallowing
  - Strongest evidence supporting stimulation of neonates to improve sucking/feeding
  - Conflicting evidence regarding short term effects of thermal-tactile stimulation
- Speech
  - No highest quality studies identified
  - Case study report showing improved speech accuracy in AOS
- Neuromuscular function
  - A small case series demonstrated improved protective reflexes following vibrotactile stimulation
  - Controlled study showed no effects of icing or vibration on genioglossus muscle tone
Conclusions

• Somatosensory function may be disrupted at various levels
  – Peripheral receptors
  – Peripheral reflexes
  – Afferent pathways
  – Central association pathways
• Documentation of unique somatosensory deficits related to specific speech or swallowing dysfunction is largely lacking

Conclusions

• Treatments targeting peripheral somatosensory mechanisms
  – Be aware of unique physiology of each muscle group
  – Best evidence relates to effects on infant feeding function
• Treatments targeting central somatosensory mechanisms
  – Should adhere to principles of training specificity

Part 2

“activities that involve actions of…”

Neuromuscular Underpinnings
Thought to Impact Speech/Swallowing

• Strength
• Muscle tone
• Stability and coordination

Weakness

• Impaired ability to produce force
  – Endurance/Fatigue
  – Power
• Causes
  – UMN lesion (UUMN and spastic dysarthria)
  – LMN lesion (flaccid dysarthria)

Assessing strength

• Peripheral muscle groups
  – Usually gauged by judging ability to produce force against resistance
    • Subjective
    • Objective
Subjective measures of strength

- Examples
  - Press against tongue blade
  - Move jaw, lips against hand/fingers
- Issues
  - Subjectivity
  - Include movements in all appropriate directions
  - No norms available

Objective measures of strength

- Examples
  - Iowa Oral Performance Instrument (IOPI)
  - Kay Swallowing Signals Lab
- Issues
  - May be more sensitive to subtle changes/differences in strength

New Advances in Orofacial Strength Assessment

Luschei created an adaptor for the IOPI to allow for objective measures of lingual pressures during lateralization and protrusion

Lingual Protrusion

Linguual Lateralization
Cheek Compression

Normative Data
- Lingual protrusion generates highest pressures
- Lingual elevation and lateralization are similar
- Most healthy participants demonstrated asymmetrical lingual lateralization & cheek compression strength

Lingual Lateralization

Assessing Strength
- Proximal muscle groups
  - Examples
    - Velum
    - Larynx
    - Pharynx
  - Issues
    - Usually inferred from function
      - ROM
      - Coup de glotte

Madison Oral Strengthening Tongue Device (MOST)
How does strength relate to speech or swallowing function?

- Oral phase dysphagia more common in patients with lingual weakness (Clark et al., 2003; Reddy et al., 1990; Robinovitch et al., 1991)
- Adults with dysarthria often exhibit reduced lingual and/or lip strength or endurance (Blankenship et al., 2002; Depaul et al., 1993; Dworkin & Aronson, 1986; Dworkin et al., 1980; Barlow & Alibs, 1983; Solomon et al., 2003; Stierwalt et al., 1996; Wood et al., 1992)

How does strength relate to speech or swallowing function?

- Children with DAS may have reduced strength and endurance (Murdoch et al., 1995; Robin et al., 1991)
- Children with developmental phonologic / articulation disorders may have reduced (Dworkin, 1978), normal (Dworkin & Culatta, 1985), or increased (Sudbery et al., 2007) lingual strength

Final Thoughts on Strength

- Speech forces are a small percentage of the maximum force that the articulators can produce
- Higher forces (but still submaximal) are required for swallowing

Assessing Coordination

- Alternate motion rates (AMR)
  – Puh puh puh
  – Tuh tuh tuh
  – Kuh kuh kuh
- Sequential motion rates (SMR)
  – Puh tuh kuh
- Nonspeech movements
  – Wag tongue back and forth
  – Alternating pucker and smile

Incoordination

- Individual movements/articulators
  – Timing
  – Sequencing
- Multiple movements/articulators
  – Timing
  – Sequencing
- Fine Force Control

Assessing coordination

- Norms are available for AMR and SMR across age groups
  – Addresses speed as well as coordination
- No norms available for nonspeech tasks
How does coordination relate to speech/swallowing function?

- Patients with UMN dysarthria demonstrate poor coordination of force changes (Barlow & Abbs, 1986)
- Patients with AOS show impaired oral tracking ability (Clark et al., 1998; Hageman et al, 1994)

How does coordination relate to speech/swallowing function?

- DDK is impaired in individuals with TBI dysarthria (Mulligan et al, 1994, Portney et al, 1982), Down Syndrome, stuttering, hearing impairment (Robb et al., 1985), and developmental articulation disorders (Dworkin, 1980)
- Children with phonologic or fluency disorders did not demonstrate abnormal DDK (Wolk et al, 1993)

Treatment Targets

- Strength
- Range of motion
- Coordination

Strength Training

- Key issues
  - Specificity of Training
  - Overload
  - Recovery
  - Progression
  - Reversibility

Specificity of Training

- The effects of strength training are highly specific to the trained behaviors
- This is primarily related to motor unit recruitment and motor learning

Review of Motor Units

- Motor unit: motoneuron and the muscle fibers it innervates
- Specific motor units are recruited for any given movement
  - Force
  - Speed
  - Direction
- Motor learning results when the brain establishes an effective pattern of motor unit recruitment to achieve the desired outcome
Factors subject to specificity

- Force
- Contraction velocity
- Duration
- Dynamics

Force

- Low force: Type I units (slow twitch)
- High force: Type II units (fast twitch)

If exercise is completed to the point of fatigue, both Type I & II are trained

Contraction velocity

- Velocity of exercise movements should match that required for the desired outcome

Dynamics

- Isometric (static): muscle changes tension while maintaining constant length
  - Stabilization
- Isotonic (concentric): muscle shortens during contraction
  - Lifting
- Eccentric: muscle lengthens during contraction
  - Controlled release

Integration

- Results of motor learning experiments suggest that motor programs (specific patterns of motor unit recruitment) are highly specific
- Predicts that exercises that incorporate the entire movement pattern (e.g., all articulators) will result in greatest carryover

Training Specificity of the Tongue

- Lingual muscle training results in non-specific outcomes
  - Training of anterior lingual elevation improves swallowing function (Robbins et al, 2005, 2007)
Testing Training Specificity of Lingual Musculature

- Competing Hypotheses
  - Training Specificity
    - Predicts that greatest gains in strength will be observed for movements that match the exercise
  - Muscular Hydrostat (ala Luschei, 1991)
    - Tongue muscles contract against each other
    - Predicts that generalized increases in lingual strength may be observed for untrained lingual movements

Clark et al (2007)

- N = 39 (22 female, 17 male)
- Mean age = 37.8 years (18 – 67)
- No history of speech or swallowing impairment

Exercises - Elevation

Push tongue up against the roof of mouth as hard as possible

Exercises - Protrusion

Exercises - Lateralization

Training Methods

- Participants randomly assigned to sequential training (n=29) or concurrent training (n=10)
- Sequential Training
  - 1 exercise (elevation, protrusion, or lateralization)
  - 3 sets of 10 maximum contractions (total: 30 reps)
  - Once per day for 3 weeks
  - Change exercise after 3 weeks, for a total of 9 weeks (order of exercise counterbalanced across subjects)
- Concurrent Training
  - All three exercises
  - 1 set of 10 of each (total: 30 reps)
  - Once per day for 9 weeks
Outcome Measures

- Pressures as measured by IOPI (examiners blinded to exercise condition)
- Lingual elevation (standard IOPI procedures)
- Lingual protrusion (utilizing IOPI lateral adaptor)
- Lingual lateralization (left & right)
- Cheek compression (left & right)
- Baseline and during each week of training, 2-4 weeks after training was discontinued

Hypothetical Results

Effects of Training Specificity

Conclusions

- The findings support the hypothesis that general training effects may be observed in the lingual musculature
- The findings provide explanatory power for earlier work demonstrating functional outcomes from non-specific training
  - Generalized strengthening
- The findings do not suggest that any one lingual exercise is more effective than another

- 5 subjects in each of 5 training conditions
  - Strength
  - Endurance
  - Power
  - Speed
  - No exercise
- After 4 weeks of exercise, changes in strength, endurance, power, and speed were assessed

**Change in Strength**

<table>
<thead>
<tr>
<th>Training Group</th>
<th>Control</th>
<th>Strength</th>
<th>Endurance</th>
<th>Power</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strength (kg)</td>
<td>12</td>
<td>14</td>
<td>16</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

**Change in Isotonic Endurance**

<table>
<thead>
<tr>
<th>Training Group</th>
<th>Control</th>
<th>Strength</th>
<th>Endurance</th>
<th>Power</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetitions</td>
<td>-20</td>
<td>-10</td>
<td>0</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

**Change in Power**

<table>
<thead>
<tr>
<th>Training Group</th>
<th>Control</th>
<th>Strength</th>
<th>Endurance</th>
<th>Power</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetitions</td>
<td>-20</td>
<td>-10</td>
<td>0</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

**Change in Speed**

<table>
<thead>
<tr>
<th>Training Group</th>
<th>Control</th>
<th>Strength</th>
<th>Endurance</th>
<th>Power</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (m/s)</td>
<td>-1</td>
<td>-0.5</td>
<td>0</td>
<td>0.5</td>
<td>1</td>
</tr>
</tbody>
</table>

**Overload & Progression**

- **Overload**
  - Taxing the muscles beyond typical functioning
  - Results in
    - Hypertrophy of muscle tissue
    - Increased motor unit recruitment
- **Progression**
  - Systematic overload
Recovery & Reversibility

- Recovery: optimal interval between training sessions to allow recovery yet avoid reversal
- Reversibility: levels of strength must be used to be maintained

Contra-indications for strength training

- Hypertonia
  - This assumption has been strongly questioned in recent years (e.g., Ashworth, Satkunam, & Deforge, 2004 Cochrane Review)
- Fatigue Susceptibility
  - This assumption is also under scrutiny; a number of studies are being published examining strength training in ALS and MS (e.g., White & Dressendorfer, 2004)
- Absence of Weakness
  - This assumption is not under scrutiny?

CPAP

- CPAP provides resistance to velar elevation
- Exercise is speech
  - VNCV (stress on 2nd syllable)
  - Sentences
- Systematically increases pressure and number of exercise repetitions

Shaker

- Head lifts
  - Isometric
  - Isotonic
- Targets laryngeal elevators
### Shaker

<table>
<thead>
<tr>
<th>Direction of movement</th>
<th>Contraction of laryngeal elevators with larynx stationary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force</td>
<td>Maximally? overloaded</td>
</tr>
<tr>
<td>Speed/Duration</td>
<td>Includes both isometric and isotonic contractions, isotonic are likely slower than swallowing movements</td>
</tr>
<tr>
<td>Integration</td>
<td>Limited – open vs. closed chain</td>
</tr>
<tr>
<td>Progression</td>
<td>Uns specified, but easily accommodated by increased number of contractions or duration/speed of sustained contraction</td>
</tr>
</tbody>
</table>

### Mendelsohn

- **Sustained laryngeal elevation during swallow**

### Mendelsohn

<table>
<thead>
<tr>
<th>Direction of movement</th>
<th>Laryngeal elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force</td>
<td>Not overloaded, except for increased effort</td>
</tr>
<tr>
<td>Speed/Duration</td>
<td>Targets more sustained isometric contraction than typical</td>
</tr>
<tr>
<td>Integration</td>
<td>Fully integrated</td>
</tr>
<tr>
<td>Progression</td>
<td>Can be accomplished by increasing duration of contraction</td>
</tr>
</tbody>
</table>

### TalkTools

**TalkTools**

- (Rosenfeld-Johnson)

- Intended to exercise lips, tongue, and velum
- Resistance progresses through varying straws and whistles

### TalkTools

<table>
<thead>
<tr>
<th>Direction of movement</th>
<th>Lip closure, lingual retraction, velar elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force</td>
<td>Maximal?</td>
</tr>
<tr>
<td>Speed/Duration</td>
<td>Moderate speed, duration brief or sustained</td>
</tr>
<tr>
<td>Integration</td>
<td>Lip, tongue, &amp; velum co-activate</td>
</tr>
<tr>
<td>Progression</td>
<td>Accomplished by different horns/straws</td>
</tr>
</tbody>
</table>

### Strength Training in Dysarthria

- **Exploratory: 4 studies**
  - Sensory stimulation plus orofacial exercise improved intelligibility of adults (Roy 2002) and children (Roy 2001). AMR rates were unchanged in both studies
  - Some studies failed to report any results
- **Lower level evidence**
  - A small number of “low n” controlled studies and/or case studies provide limited support
  - Most authors caution against emphasizing strength training over speech-directed treatment, but acknowledge the potential benefit for specific patients when appropriate principles are incorporated (Gronhinn, Linkebaugh, Hageman, Duffy, Yektat, Love, Mandich)
Evidence supporting strength training in dysphagia

- **Efficacy (2 studies)**
  - Standard Oral Motor Exercise + diet supplement
    - Greater weight than supplement alone in healthy elderly
  - Head Lifts
    - Improved functional swallowing rating and restored oral feeding in pts with reduced UES opening

- **Exploratory (6 studies)**
  - Lingual exercises
    - Improved swallowing pressures in healthy aging adults
  - Combined standard swallowing exercises (Mendelsohn, Shaker, Masako, lingual resistance before and during radiation)
    - Improved QOL scores by radiation patients
  - Chewing exercises
    - Masticatory efficiency decreased immediately following training in healthy adults
  - Head Lifts
    - Improved anterior laryngeal excursion and increases UES opening in healthy adults
  - Standard OME + Palatal Plate
    - Stroke patients reported improved swallowing function

Evidence supporting strength training in artic/phonologic disorders

- Lof (2006) Review (included all OME)
  - OME alone does not improve speech production
  - OME in combination with speech treatment does not improve speech more than speech treatment alone

- ASHA EBSR
  - No efficacy studies
  - No exploratory studies

Strength Training in VPI

- **Efficacy: none**
- **Exploratory:**
  - Blowing & sucking exercises had no effect on nasality ratings (Powers & Starr, 1974)
- **Lower Levels of Evidence**
  - CPAP (using speech) has positive effect on nasality ratings (Kuehn, 2002)

Stimulated Exercise

- **Exercise:** Roughly defined as a technique that results in muscle contraction
- **Volitional Exercise** (aka Active Exercise)
  - Involves CNS and PNS mechanisms
- **Stimulated Exercise** (aka Passive Exercise)
  - Involves PNS mechanisms only

NMES

- **Uses electricity to cause muscle contraction**
  - Electrode Sites
    - Surface
    - Percutaneous
    - Intramuscular
  - Current parameters
    - Amplitude, duration, & frequency
    - Intensity
    - Waveform (pulsed most common)
    - Bursts
  - Has been applied to limb musculature to increase strength, but is most often used in conjunction with active exercise
NMES

- NMES contractions differ from volitional contractions
  - Reverse order of motor unit activation
  - Absence of graded contraction
- Results of NMES
  - Fatigue, particularly with high frequency NMES
  - Change of muscle composition (greater proportion of slow twitch fibers)

Time Machine
(Stefanakos)

- NMES of Face
  - Pulsed currents
  - Low Amplitude
- Criticisms
  - Risk of synkinesis
  - Does not speed recovery in Bell's Palsy

Probably doesn't even reduce wrinkles!

VitalStim™

- Electrical stimulation applied to neck musculature
  - Purported to stimulate laryngeal and pharyngeal musculature
  - Paired with active exercise

VitalStim™

Questions about VS

- Which muscles are being stimulated?
- What happens to the swallowing structures when stimulation is applied?
- What are the implications of pre-contracted muscles?
- What are the optimal stimulation parameters?

Evidence supporting NMES for Speech

- No efficacy or exploratory studies qualified for review

Evidence supporting NMES for Dysphagia

- Carnaby-Mann & Crary (2007) Systematic Review
  - 7 studies accepted for analysis
  - 255 patients studied
  - 2 controlled trials
  - 5 used before/after (case series) design
  - All studies used Transcutaneous stimulation applied to throat
  - 20% improvement in swallowing function (collapsed across all studies) but actual outcome measures varied across studies
  - Methodological flaws not addressed
NMES for Dysphagia (Adults)

- Efficacy (4 studies)
  - NMES applied to tongue resulted in reduced difficulty in swallowing as reported by subjects with Sjogren’s syndrome
  - VitalStim™
    - No impact on pharyngeal physiology, diet advancement or return to oral feeding (Kiger et al 2006)
    - Overall swallowing severity improved more with VS compared to TTS (Freed et al 2001) or traditional treatment (Blumenfeld et al 2006)

NMES for Dysphagia (Exploratory)

- VitalStim (3 studies)
  - Normals: reduced laryngeal and hyoid elevation during stimulation
  - Patients
    - Stimulation on: hyoid lowers at rest, improved swallowing on some measures, not on others
    - Stimulation over time: greater improvement with VS compared to TDT; improved oral intake and swallowing physiology (not laryngeal elevation)
  - Neck Surface (not VS – 2 case series)
    - Improved swallowing outcomes & increased cortical representation
    - One study applied 4 hrs of stim per day, up to 30 days

NMES for Dysphagia (Exploratory)

- IM (1 study with normals)
  - Repeated stimulation does not reduce muscle activity when stimulation is discontinued

- Transnasal Pharyngeal Stimulation (2 studies)
  - Improved pen/asp scores and reduced PTT

Expert Opinion?

- Appears to be a sense of general optimism about NMES as a treatment modality, given appropriate caution about precise treatment protocols and patient populations

Future of NMES

- Feedback control (Functional Electrical Stimulation)
  - Onset of stimulation triggered by detection of muscle activity on EMG
- Differential muscle recruitment strategies

DPNS

- Cold, sour, pressure stimulation applied to oropharyngeal mucosa to elicit protective reflexes
- Arguably, DPNS is both
  - Sensory treatment
  - Stimulated Exercise
DPNS

- Physiologic rationale
  - Stimulation sites activate CN IX, X receptors with NTS -> NA
  - Heighten sensitivity of receptors
  - Elicit NA efferents to involuntarily contract velar, pharyngeal and lingual musculature

DPNS

- Theoretical questions
  - Noxious -> protective reflexes
  - Pleasing -> swallowing responses
- Evidence
  - Anecdotal only

Active Stretching

- Unlike strength-training, the goal of stretching is increased range of motion (ROM) not increased strength
- Functional strength may be influenced by length/tension relationships (e.g. Fitsimones, 2004)

Principles of Stretching

- Specificity: target ROM for relevant movements
- Slow stretching generally most effective

Mendelsohn: Combining strength training and stretching

Evidence supporting stretching in SLP

- Efficacy: No studies
- Exploratory: Mendelsohn?
- Lower Level:
  - ROM performed 10 min 10x daily (!)
  - Positive effects on liquid swallow effectiveness
- Expert Opinion: Stretching is commonly described in texts as a strategy for addressing hypertonia (Dworkin, Duffy)

Coordination Training

- Any non-speech activity targeting positioning and/or sequencing of movements of one or more articulators
OME in Artic/Phonologic Disorders

- Efficacy (3 studies -- Tongue Thrust)
  - Children receiving OME displayed tongue tip placement similar to those receiving traditional articulation tx
  - Children receiving “Face Former” tx displayed orofacial speech movements similar to those receiving traditional myofunctional tx
  - One study failed to report outcomes

OME in Artic/Phonologic Disorders

- Exploratory
  - Tongue thrust tx
    - Reduced frontal lisp (nature and amount of tx unspecified)
    - One study failed to report outcomes
  - Easy Does It for Articulation: no effect of GFTA

What’s all the fuss about?

- Sensorimotor applications in linguistically based communication impairments
- Unclear associations between sensorimotor functions and speech integrity (better evidence in the area of swallowing)
- Sensorimotor treatments instead of speech treatment

What’s all the fuss about?

- Exercise protocols that do not incorporate well-established strength-training principles
  - Dosage?
  - Frequency?
  - Intensity?

What’s all the fuss about?

- Sensorimotor treatments that target peripheral mechanisms that don’t exist
- Methods for describing neuromuscular and central effects of sensory treatments
- Commercial/financial interests
- Ivory tower bias
- High quality treatment research
Oral Motor Concluding Remarks

• Quality evidence supporting the use of sensorimotor treatments is limited, particularly with respect to speech targets.

• Philosophical rationale for incorporating sensorimotor interventions anyway
  – Clear understanding of NM impairment
  – Reasonable expectation that OMT will affect speech/swallow musculature
  – Absence of contraindications
  – OMT serves as one facet of a holistic management plan

Image Sources

• National Down Syndrome Society
• Talk Tools
• CPAP Shop
• Medline Plus
• Theraquip
• Sarah
• Julie Mills, CCC/SLP
• Singular Thomson Learning
• IOPI Northwest
• University of Scranton - Department of Physical Therapy
• Kinesio Tape®
• University of Wisconsin Neuroscience Tutorial
• Washington University School of Medicine Neuroscience Tutorial