Respiratory Muscle Strength Training

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The Beginning....

• What is Respiratory Muscle Strength Training?
• Why use it?
• Who can we use it with?
• Review of Outcomes
• Detraining Considerations
• Maintenance
• Next Steps...
Intervention

- Science
- Clinical Knowledge
- Evaluation and Planning
- Proof of Concept
- Safety
- Effectiveness
- Future Trials
Questions to Think About

• Do you need *active* respiratory muscles for your daily needs?
• Can respiratory muscles be conditioned?
• Are all respiratory strength training devices the same?
• Once you train, the strength you gain never goes away?
• Who can benefit?

Scholz, Klein, Behrens, Johansen-Berg, Nat Neurosci, 12, 11, 1370-1371.
What is Plasticity?

- Neural adaptations (6-8 weeks)
- Myogenic adaptations (+ 5 weeks)

(Modified from Sale, 1988)
I believe...

• As Speech Pathologists – we generally are concerned with functional outcomes
  • Results from limb and hand studies suggest that resistance/strength training changes the functional properties of spinal cord circuitry in humans, but does not substantially affect the organization of the motor cortex.
  • How does Neuroplasticity differ from Behavioral Plasticity?
  • If we are achieving functional outcomes why does proving neuroplasticity even matter?
Plasticity Occurs in Response to Numerous Stimuli

- Peripheral Input
- E-Stimulation
- Drugs
- Disease
- Injury
- Experience

Plasticity leads to neural sprouting, synaptogenesis, and dendritic metabolic demand and leads to angiogenesis, synapto genesis and synaptic.
Ten Principles of Experience-Dependent Plasticity

1. Use it or Lose it
   Failure to drive specific brain functions through training can lead to the degradation of that function.

2. Use it and Improve it
   Training that drives a specific brain function can lead to an enhancement of that function.

3. Plasticity is Experience Specific
   The nature of the training experience dictates the nature of the plasticity.

4. Repetition Matters
   Induction of plasticity requires sufficient repetition.

5. Intensity Matters
   Induction of plasticity requires sufficient training intensity.
Ten Principles of Experience-Dependent Plasticity

6. Time Matters
   Different forms of plasticity occur at different times during training.

7. Salience Matters
   The training experience must be sufficiently salient to induce plasticity.

8. Age Matters
   Training induced plasticity occurs more readily in younger brains.

9. Transferance
   Plasticity that occurs in response to one training experience can enhance the acquisition of similar behaviors.

10. Interference
    Plasticity that occurs in response to one training experience can interfere with the acquisition of other behaviors.
Experimental Paradigms

• We capitalize on symptoms: weakness, and discoordination.
• 1st you need to show that you can change strength or force production.
• In XXX patients with PD (H & Y, stage II-III) MEP has changed by over a 4 week training period.
• This is similar to recent findings of strength training
  – For example studies show increases in maximal dynamic and isometric muscle strength of the biceps by 31% (P < 0.001) and 12.5%
Paradigm Strength Training:

• Works on restoring the capacity of a group of muscles to generate and time the necessary forces for a particular task.

• Produces an effective pattern of coordination specific to the contexts in which the action is performed (Hegland, Troche, Plowman)
Principles

Specificity

Overload

(DeLorme, 1946)
Specifity and Overload Principles

• To increase their functional ability, muscle fibers must be taxed toward their present capacity to respond.

• In daily activities, muscles are undergoing gravitational forces. An increase in gravitational forces (hypergravity) is required to increase neuromuscular performance.

(Hennemann, 1965)
The Baseline Measure of Force Measuring MEPS
What is a Manometer?

Pressure Gauge
Measures any type of pressure
How to Cheat…
You Breathe with Your Brain

• Respiratory mechanical parameters:
  – Volume, pressure, flow, volume

• Respiratory Mechanical Status (Interactions)
  – Airway Resistance = airflow/pressure
  – Compliance = volume/pressure
  – Pressure Threshold = pressure * force
  – Impedance = resistance + compliance
  – Work = pressure & volume & time
  – Cognitive awareness of mechanical status of respiratory systems, dual task
What is EMST?

- Expiratory pressure threshold training:
  - Pressure-threshold device
  - Spring-loaded valve
  - *Not* resistance training (physiological load calibrated and imposed)
  - Target muscles: expiratory and supralaryngeal

4 week program
5 days per week
25 breaths per day
Load set at 75% of MEP
Provides specific, constant, pressure load (spring loaded valve 0-150 cm/H₂O)

- Loaded Spring
- Mouthpiece
- Adjustable Valve

- Within Subject Use
- 5 days/week
- 25 trials for total set
- Magic number?
Normal Breathing

Breathing with a Pressure Threshold Load

Diaphragm
EMG

Pressure

Diaphragm
EMG

Normal Breathing

Breathing with a Pressure Threshold Load

Diaphragm
EMG

Pressure
Amplitude

Normal Swallow

Trainer setting 20 cmH₂O

Max Exhalation

R Submandibular

L Submandibular

R Sternohyoid

L Sternohyoid

Trainer setting 40 cmH₂O

Trainer setting 65 cmH₂O
Use-dependent Model of Plasticity

- sEMG activation of submentals (Wheeler et al., 2005)
Strength Defined by Changes in MEP

![Graph showing changes in MEP over baselines from Pre to Last.]
• Weakness and discoordination of the respiratory muscles can dominate the clinical manifestations in the later stages of several primary neurologic and neuromuscular disorders in a manner unique to each disease state.
Parkinson’s Disease

• PD: A debilitating neurological disorder affecting the human body in a way that limits a person's ability to control muscle movement.

• Respiratory dysfunction exists, yet the pathogenesis is unclear.

• Lower airway obstruction, lower airway restriction, upper airway obstruction, and muscle weakness.

• Respiratory system involvement is REAL - is more than what is perceived - and pneumonia is one of the common causes of death in this disorder.
Reductions in Respiratory Muscle Strength

- Maximum Inspiratory and Expiratory Pressures
Respiratory Characteristics

• Abnormal flow volume loops, reduced maximal inspiratory and expiratory airflows and pressures, reduced peak expiratory airflow rates, and decreased vital capacities have all been implicated

• “Cogwheel" breathing pattern

• Respiratory dysrhythmias
In the 71 Parkinson’s Disease (PD) patients we have run to date, we are finding a Restrictive Component to Breathing

- The restrictive defect has been explained on the basis of poor chest wall compliance related to muscular rigidity
- Agrees with Banerjee et al., 1997
How we intervened...

Respiratory muscle strength training:
Treatment and response duration in a patient
with early idiopathic Parkinson’s disease

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Tutorial on maximum inspiratory and
expiratory mouth pressures in individuals
with idiopathic Parkinson disease (IPD) and
the preliminary results of an expiratory
muscle strength training program\textsuperscript{1}

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CHEST
Original Research
COUGH AND ASPIRATION

Impact of Expiratory Muscle Strength
Training on Voluntary Cough and
Swallow Function in Parkinson Disease

Teresa Pitts, MA; Donald Bolser, PhD; John Rosenbek, PhD;
Michelle Troche, MA; Michael S. Okun, PhD; and Christine Sapienza, PhD
Breathing and Swallowing
Intimately Connected

• Life Sustaining Functions
• Impairment impacts quality of life but..
• Impairment impacts vitality
• Aspiration Pneumonia
  – Disordered Swallowing Infiltrates the Airway
  – Airway Compromise Alters timing of Airway Protection
  – The risk of aspiration increases for a number of reasons but one of the reasons is the absence of an Apneic period or a reduction of its duration.
Delay
Tongue pumping can cause increased oral transit times and therefore increased eating time for the patient.

Do swallowing exercises improve swallowing dynamic and quality of life in Parkinson's disease?
Argolo N¹, Sampaio M, Pinho P, Melo A, Nóbrega AC.
Response to Dopaminergic Medications

• Nilson and colleagues (1996) assert that oral and pharyngeal function in PD are not the result of reduced dopamine levels, therefore L-Dopa is ineffective (supported also by Born et al, 1996; Hunter et al, 1997; Leopold et al, 1997).

• The strongest theory as to the ineffectiveness of dopaminergic medications in PD swallow is the dual involvement of muscle tissue which is both striated and smooth.
Methods: Design

Prospective, blinded, randomized, sham-controlled, clinical trial
Randomly assigned to active or sham treatment group
Baseline swallow assessment followed by 4 weeks of EMST/sham intervention
Post intervention assessment followed completion of treatment arm

Videofluoroscopy:
- 10 x 5 mL thin (cup); 1 x 3 oz thin sequential (cup)
- Presented in randomized fashion

• Cough Function: Voluntary, pneumotachograph
Types of Measures

- Breathing
- Cough
- Swallow
- Voice
- QOL
The Hyoid Bone Movement
In the “unsafe” swallow the first three events have occurred within the first four frames, whereas in the “safe” swallow the bolus doesn’t arrive at the ramus until the twelfth frame.

Although the pattern of movement is similar, in the “safe and “unsafe” swallows
# Measures of Swallow Timing

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onset of OTT</td>
<td>Point at which the tongue tip is raised and the bolus begins posterior movement towards the posterior aspect of the oral cavity.</td>
</tr>
<tr>
<td>Offset of OTT</td>
<td>Point at which the tail of the bolus passes the level of the ramus of the mandible.</td>
</tr>
<tr>
<td>Onset of PTT</td>
<td>Point at which the leading edge of the bolus passes the level of the ramus of the mandible.</td>
</tr>
<tr>
<td>Offset of PTT</td>
<td>Point at which the tail of the bolus passes through the upper esophageal sphincter (UES).</td>
</tr>
<tr>
<td>No. of tongue pumps</td>
<td># of times the tongue pumps (rocks) while the bolus is in the oral cavity.</td>
</tr>
</tbody>
</table>
# Measures of Swallow Safety

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Contrast does not enter the airway</td>
</tr>
<tr>
<td>2</td>
<td>Contrast enters the airway, remains above the vocal folds</td>
</tr>
<tr>
<td>3</td>
<td>Contrast remains above the vocal folds with visible residue</td>
</tr>
<tr>
<td>4</td>
<td>Contrast contacts vocal folds, no residue</td>
</tr>
<tr>
<td>5</td>
<td>Contrast contacts vocal folds, visible residue</td>
</tr>
<tr>
<td>6</td>
<td>Contrast passes glottis, no sub-glottic residue</td>
</tr>
<tr>
<td>7</td>
<td>Contrast passes glottis, visible sub-glottic residue, despite patient response</td>
</tr>
<tr>
<td>8</td>
<td>Contrast passes glottis, visible sub-glottic residue, absent of patient response</td>
</tr>
</tbody>
</table>

(Penetration-Aspiration Scale; Rosenbek et al., 1996)
What is Cough?

- Cough is a mechanism that protects the pulmonary system by generating expiratory airflow that create a “scrubbing” action removing material from the airway. (Leith, Butler, Sneddon & Brian, 1990; Smith Hammond, et al, 2001).

- To generate high linear airflow velocities during cough three things must occur: inspiration, closure of the vocal folds, & forced expiration.
Cough: beyond just removal
Cough Function

• Relates to inspiratory muscle and expiratory strength

• These measurements are related to the ability to generate transient supramaximal flow during a cough (cough spikes)
The Importance of Airway Clearance

The graph shows the relationship between amplitude and inspiratory phase with respect to peak expiratory flow. The levels are categorized as Weak, Moderate, and Strong.
4. Severe Aspiration
Flow (L/s)

Time (msec)

Pre Strength Training

Post Strength Training

Peak flow
Important to know

- Muscles do respond to training
- That combined modality treatments need to be investigated
  - Drug plus Behavioral
  - Behavioral plus Behavioral

- That working on one subsystem may cross over to positively influence a second system.
Most participants who trained with the sham device were surprised to find out they were not training with the “real” device.

Many reported improvements in their speech and swallow – which were not necessarily corroborated by our objective measures.

We had no participants drop from the study because of dislike for the training paradigm itself.

Compliance was monitored by weekly visits by a clinician, a daily log sheet kept by the participant, and random phone calls by the clinician/researcher.
A Bit about Placebo

• You are the Placebo – Joe Dispenza
• In the same decade that Kandel and others measured neuroplasticity, other scientists discovered that few of our genes are static. The majority of genes (estimates range from 75 to 85 percent) are turned off and on by signals from our environment, including the environment of thoughts, beliefs, and emotions that we cultivate in our brains.
• Self-directed neuroplasticity (or SDN). The idea behind the term is that we direct the formation of new neural pathways and the destruction of old ones through the quality of the experiences we cultivate.
Dr. Emily Plowman