Effortful Pitch Glide: An Exercise for Potential Swallow Rehabilitation Evaluated by Dynamic MRI

Keri Vasquez Miloro, MS, CCC-SLP, BRS-S
William G. Pearson, Jr. PhD
Susan Langmore, PhD, CCC-SLP, BRS-S
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William Pearson: Training grant No. F31DC011705 from the National Institute on Deafness and Other Communication Disorders

Susan Langmore: NIH-NCI R01-CA120950-05
Board Recognized Specialist in Swallowing and Swallowing Disorders (BRS-S)

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Presentation Objectives

1. Principles of exercise training

2. EBP review of current swallow therapy
   - Application of training principles, targeted kinematics & comprehensibility

3. Overview of study examining the EPG
Training Principles

1. Specificity
   - Muscular response – action or contraction
   - Swallow therapies – kinematic specificity

2. Overload
   - Intensity, freq, duration (reps, sets, rest)
Training Principles

Goal - Adaptation
- Muscle response
  - Fiber shifts and hypertrophy (Burkhead et al 2007)

- Maintenance/Detraining
  - Loss of adaptations gained
Other Principles

Transference

“the ability of plasticity within one set of neural circuits to promote concurrent or subsequent plasticity” (Kleim & Jones, 2008, p. S232)

- Behavioral plasticity (Robbins et al, 2008)
Rehabilitative Swallow Therapies

Goal – Improve physiology
Force, speed and timing

Exercise program to promote LT effects
Two types of exercise

1. Swallow maneuvers: “task-specific” exercises

2. Non-swallow (non-specific) exercises

Aim: long-term – make the swallow stronger, quicker, more coordinated
Part 1: “Swallow” Exercises

1. Mendelsohn maneuver
2. Effortful swallow
3. Supraglottic swallow maneuver
4. Tongue-hold
5. MDTP
Mendelsohn Maneuver (MM)

↑ laryngeal elevation, greater amplitude during swallow (Kahrilas et al 1991)

- Sig. improved superior and ant hyoid post 2 weeks of MM (McCullough et al 2012)
  - sEMG

- **Application of training principles**: specificity, overload

- **Kinematics**: hyolaryngeal elevation, anterior hyoid

- **Comprehensibility**: Difficult

*Based on clinical experience*
Effortful Swallow (ES)

- **Principle:** BOT – PPW

- Lengthened laryngeal closure, improved hyoid excursion, UES opening duration, higher oral pressures (Hind et al 2001)

- ↑ in submental activity vs swallow (Wheeler – Hegland et al 2008)

- Delayed pharyngeal & UES events *but > pharyngeal pressure and UES relaxation* (Hiss & Huckabee, 2005)

- Increases esophageal amplitude (Nekl et al 2012)

- **Application to training principles:** specificity, overload

- **Kinematics:** Pharyngeal contraction, airway closure, UES

- **Comprehensibility:** Difficult, often taught w/ biofeedback
Cortical Activity

ES and MM elicited widespread neural network of activation in both hemispheres

- Elicited more response in regions associated related to swallowing – suggesting enhanced cortical activation (Peck et al 2010)
SGS

- VF closure before and during swallow (Martin et al. 1993)
- Increased posterior and superior excursion of hyoid w/ longer displacement vs swallow (Kasahara et al. 2009)

- **Application to training principles:** specificity, overload
- **Kinematics:** Laryngeal closure, hyoid excursion
- **Comprehensibility:** Difficult
Tongue-Hold

- Significant increase in anterior bulging of PPW (Fujiu et al 1996)
  - Immediate effects

- No difference in pharyngeal pressures between tongue-hold and saliva swallows (Umeki et al 2009)

- Healthy subjects: RCT x’s 4 weeks
  - No change in swallow (hyolaryngeal ex, pharyngeal constriction or ant movement of PPW) (Oh et al 2012)

- **Application to training principles:** specificity, overload
- **Kinematics:** pharyngeal bolus transport, BOT
- **Comprehensibility:** Difficult
McNeill Dysphagia Tx Protocol (MDTP)

“Swallow hard and fast” - follows a dietary hierarchy with advancing steps of altered bolus volume (load) and consistency

- Increased laryngeal and hyoid elevation, lingual-palatal pressures, FOIS, oral and pharyngeal temporal events (Crary et al 2012, Lan et al 2012)
- Pilot studies/small sample size

- Application to training principles: specificity, overload
- Kinematics: laryngeal and hyoid elevation
- Comprehensibility: Difficult (MMSE > 23)
Part 2: Non-swallow exercises

1. Shaker
2. Tongue strengthening
3. LSVT
4. EMST

Falsetto

Pharyngeal squeeze maneuver

*more on these later.....*
Shaker Exercise

Strengthens suprahyoids for forward movement; Reduces post-swallow pyriform sinus residue d/t decreased UES excursion

- **Significant improvement** - UES opening, anterior laryngeal excursion and elimination of aspiration post swallow
  
  (Shaker et al 2002)

- **Application of training principles:** Overload, transference
- **Kinematics:** Anterior laryngeal movement
- **Comprehensibility:** easy BUT ↓ tx compliance
Shaker Exercise

Elderly subjects - Increase in frequency range and intensity (Easterling 2008)

Suggestive of transference
Tongue Strengthening

Isometric lingual resistance exercise using the Iowa Oral Performance Instrument (IOPI)

- ↓ residue, pen/asp, oral transit duration, lengthened airway protection and improved QOL; increased lingual muscle mass (Robbins et al, 2007)

Improved tongue strength and swallow function; improved diet levels (Yeates et al 2008)
Tongue Strengthening (cont)

Tongue depressors

- Young normals - no differences in strength between depressors versus IOPI (Lazarus et al, 2003)

- Healthy adults - *increased* lingual strength
  - elevation, lateralization and protrusion

- Detraining effects - lingual strength *decreased* 2-4 weeks after training (Clark et al, 2009)
Tongue Strengthening (cont)

- **Application of training principles:** Overload, transference
- **Kinematics:** bolus flow, airway closure
- **Comprehensibility:** easy – difficult
Lee Silverman Voice Tx (LSVT)

- Improve speech intelligibility in PD
  - MPD, F0, fxnl phrases, speech tasks;
  - Talk and think “LOUD!” (Ramig et al 1995)

- Improved lingual motility, quicker swallow, oropharyngeal TT, < vall residue
  - No change in penetration (El Sharkawi et al 2002)
  - Pilot study

- **Application of training principles:** Overload, transference
- **Kinematics:** oral transit
- **Comprehensibility:** easy
Expiratory Muscle Strength Training (EMST)

- Respiratory strengthening - resistive loading with a pressure threshold device
  - Improves cough, speech, breathing and swallow function (Sapienza et al 2006, Troche et al 2010)
  - Increased activation & higher amplitude of submentals vs. swallow (Wheeler et al 2007)
EMST

- Significant ↓ PA scores in PD post 4 weeks (Pitts et al 2009)

- RCT w/ PD – EMST vs. sham exercise
  - ↓ PA scores and ↑ hyolaryngeal fxn (Troche et al 2010)
  - MMSE ≥ 24

- Detraining – Small loss of strength post 8 weeks but significantly above baseline levels (Baker et al 2005).
EMST (cont.)

- Integration and coordination of several related muscle areas
  - neuroplastic changes (Sapienza & Wheeler 2006)

- **Application of training principles:**
  - Overload, transference

- **Kinematics:** Hyolaryngeal, laryngeal closure

- **Comprehensibility:** easy-difficult BUT need device
Effortful Pitch Glide (EPG)
What is the Effortful Pitch Glide (EPG)?

Background
What is the Effortful Pitch Glide (EPG)?

New exercise
- Easy
- Recruits muscles used in swallowing
  - Kinematic specificity
What is the EPG?

1. Falsetto

- Pitch elevation
  - Max $F_0$ and perceptual - significantly predicted PAS scores
  - Lower max $F_0$ - significantly higher mean residue scores (Malandraki et al 2011)
What happens during pitch elevation?

- MRI
  - Rising of hyoid and larynx, hyolaryngeal approximation (*Miller et al 2011*)
What is the EPG (continued)?

2. Pharyngeal squeeze maneuver (PSM)

- Evaluation of pharyngeal constrictors (*Bastian 1993*)
- PSM validated when compared with the pharyngeal constrictor ratio (*Fuller et al 2009*)
What is the EPG?

Pitch glide + PSM = EPG
Video of EPG
Aims

#1: Describe the EPG

#2: Test for swallowing specificity using two-planar dynamic dynamic MRI
Methods

- 11 healthy, young subjects
  - mean 25.4 years (range 22- 30 yrs)
  - 6 M, 5 F

- Used laryngoscopic exam to describe EPG (Aim #1)
  - Instructions:
    1. /i/ modal pitch - highest pitch
    2. Forceful “ee” sound at highest pitch
Methods (continued)

- Used two-planar T1 weighted dynamic MRI at 8.3 frames per second alternating coronal and sagittal planes to measure kinematic variables to test specificity (Aim #2)
  - 9 anatomical landmark measurements
  - Image J software
Data Analysis

- Paired two-tailed t-test with Bonferroni Correction

- Inter-reliability
Effortful Pitch Glide

Before EPG

EPG -maximum
Aim 2:

*Does the EPG elicit similar kinematic movements as swallowing?*

1. EPG>SW
2. EPG≈SW
3. EPG<SW

- Kinematic variables include:
  - Hyoid Movement
  - Hyolaryngeal Approximation
  - Laryngeal Elevation (*Superior hyoid & Posterior thyroid*)
  - Pharyngeal Shortening
  - Pharyngeal Wall Medialization
Kinematic Variables of Interest

*Hyoid Movement – Anterior*
Kinematic Variables of Interest

*Hyoid Movement – Superior*
Kinematic Variables of Interest

Hyolaryngeal Approximation
Kinematic Variables of Interest

*Laryngeal Elevation via Posterior Thyroid*
Kinematic Variables of Interest

Pharyngeal Shortening
Kinematic Variables of Interest

Pharyngeal Wall Medialization
EPG compared with the swallow – midsagittal

Swallow at max

EPG at max
EPG compared with the swallow – Coronal plane of lateral pharyngeal walls

Swallow at max

EPG at max
Results

<table>
<thead>
<tr>
<th></th>
<th>EPG Rest to Max (cm)</th>
<th>Swallow Rest to Max (cm)</th>
<th>p values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(95% Confidence Intervals)</td>
<td>(95% confidence intervals)</td>
<td></td>
</tr>
<tr>
<td>Anterior Hyoid</td>
<td>1.02±0.56 (0.69, 1.35)</td>
<td>1.02±0.34 (0.82, 1.22)</td>
<td>0.98</td>
</tr>
</tbody>
</table>

Anterior Hyoid

![Anterior Hyoid Graph]

- EPG
- Swallow
## Results

<table>
<thead>
<tr>
<th>Super Hyoid Movement</th>
<th>EPG Rest to Max (cm) Mean ± SD (95% Confidence Intervals)</th>
<th>Swallow Rest to Max (cm) Mean ± SD (95% confidence intervals)</th>
<th>p values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superior Hyoid</td>
<td>0.49±0.68 (0.09, 0.89)</td>
<td>1.37±0.73 (0.94, 1.8)</td>
<td>0.00*</td>
</tr>
</tbody>
</table>

### Superior Hyoid

![Graph showing EPG and Swallow Rest to Max (cm) comparison](image-url)
## Results

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<tr>
<td></td>
<td>Mean ± SD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hyolaryngeal</td>
<td>0.27±0.28</td>
<td>-0.17±0.5</td>
<td>0.02</td>
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<tr>
<td>Approximation (cm)</td>
<td>(0.11, 0.43)</td>
<td>(-0.47, 0.13)</td>
<td></td>
</tr>
</tbody>
</table>

### Hyolaryngeal Approximation

![Graph showing Hyolaryngeal Approximation](image)
### Results

<table>
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<tr>
<th>Laryngeal Elevation via Posterior Thyroid</th>
<th>EPG Rest to Max (cm)</th>
<th>Swallow Rest to Max (cm)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD (95% CI)</td>
<td>Mean ± SD (95% CI)</td>
<td></td>
</tr>
<tr>
<td>Laryngeal Elevation(by Posterior Thyroid)</td>
<td>1.4±0.65 (1.02, 1.78)</td>
<td>1.61±0.64 (1.23, 1.99)</td>
<td>0.3</td>
</tr>
</tbody>
</table>

**Bar Chart**

Laryngeal Elevation via Posterior Thyroid

- **EPG**
- **Swallow**
## Results

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<td>Mean ± SD (95% CI)</td>
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<td></td>
</tr>
<tr>
<td>Pharyngeal Shortening</td>
<td>1.3±0.69 (0.9, 1.7)</td>
<td>0.96±0.67 (0.56, 1.36)</td>
<td>0.2</td>
</tr>
</tbody>
</table>

**Pharyngeal Shortening**

![Pharyngeal Shortening Graph](image)
## Results

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<td>(95% Confidence Intervals)</td>
<td></td>
<td>(95% confidence intervals)</td>
<td></td>
</tr>
<tr>
<td>Lateral Pharyngeal Wall Medialization</td>
<td>1.81±0.68 (1.41, 2.21)</td>
<td>2.29±0.51 (1.99, 2.59)</td>
<td>0.16</td>
</tr>
</tbody>
</table>

### Graph: Lateral Pharyngeal Wall

- **EPG**
- **Swallow**
Kinematic Variables (EPG vs Swallow)

Inter-rater reliability $r = .76-.97$
What does this tell us about muscle activity?
All muscles except thyrohyoid and ant diagstric achieved sig. effect size changes

Muscle overload with EPG – mylohyoid (hyoid elevation), palatopharyngeus and stylopharyngeus (posterior laryngeal elevation, pharyngeal shortening)

(Pearson, W et al 2012)
How do we interpret this?

- EPG demonstrates kinematic specificity to swallowing:
  - Anterior Hyoid Movement
  - Hyolaryngeal Approximation
  - Laryngeal Elevation
  - Pharyngeal Shortening
  - Pharyngeal Wall Medialization
How does the EPG compare to other therapies?

**Application of training principles:**
Overload, transference

**Kinematics:**
Anterior hyoid, hyolaryngeal approximation, laryngeal elevation, pharyngeal shortening and pharyngeal wall approximation

**Comprehensibility:**
Easy
Limitations

- MRI
- Can this exercise be detrimental?
- No acoustic or perceptual measurements
- Young, healthy subjects – small sample
In Conclusion

We have introduced the Effortful Pitch Glide (EPG), a non swallow exercise, that may effectively resemble certain swallowing kinematics including:

– Anterior Hyoid Movement
– Hyolaryngeal Approximation
– Laryngeal Elevation
– Pharyngeal Shortening
– Pharyngeal Wall Medialization
Thank you for your attention!

Kav21@bu.edu
References


References


References


