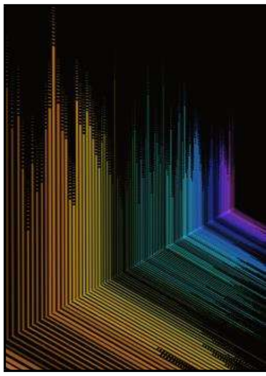

INTEGRATING MEASURES OF RESPIRATORY AND COUGH FUNCTION INTO DYSPHAGIA MANAGEMENT

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LEARNING OBJECTIVES

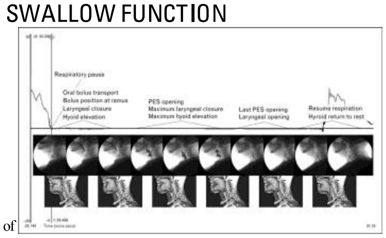
Explain	the relationship between respiratory, cough, and swallow function in healthy adults
Describe	changes in respiratory, cough, and swallow function that occur due to underlying respiratory and neurological diseases
List	evidence-based methods of assessing and treating respiratory and cough function for management of patients with dysphagia.

WHY CONSIDER PULMONARY FUNCTION?

- Pulmonary defenses (coughing, airway protection as we swallow) — Anatomical, mucocillary, reflexes, cellular
- Neurophysiology of breathing and swallowing — Central pattern generators
- Necessity of breathing and swallowing coordination
- Patients who are neurologically or respiratory compromised (i.e. ALS, COPD)
- Considerations in the clinical setting- O2 requirement, respiratory rate, SpO2, source of O2, (nasal cannula, BiPAP, CPAP, non breather mask), etc.

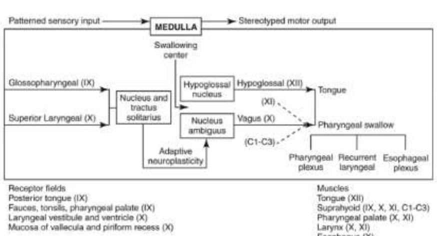
RELATIONSHIP BETWEEN RESPIRATORY, COUGH, AND SWALLOW FUNCTION

- **Respiratory, cough, and swallow function are highly integrated**
  - Shared anatomy and neurophysiology
  - Respiratory-swallow coordination
  - Respiratory/neurological diseases
  - Assessment and treatment of swallowing



(Martin-Harris, 2008)

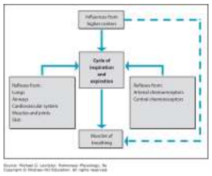
ANATOMY & PHYSIOLOGY OF SWALLOWING

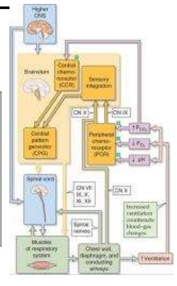


Groher & Crary, 2020

NEUROPHYSIOLOGY OF THE RESPIRATORY SYSTEM IN HEALTHY STATES

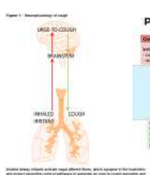
- Respiratory CPG in the medulla
  - DRG neurons
  - VRG neurons
- Can be modulated by:
  - Cortical brain regions
  - Sensory input from reflexes, chemoreceptors, muscles of breathing

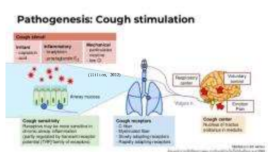




NEUROPHYSIOLOGY OF COUGH

- Cough is:
  - a protective mechanism
  - consists of four phases
  - laryngeal (expiratory reflex) and tracheobronchial





MINUTE VOLUME

- Tidal volume (Vt) x Respiratory rate (RR) =MV Minute volume
- Example: at rest, healthy
  - Vt = 500mL per breath; RR = 20/minute.
  - (500 x 20) = 10,000 mL / minute (constant)
- Disease:
  - If Vt drops to 400mL per breath (lung disease)….
  - (400mL x [RR]) = 10,000 mL / minute
  - RR = 25 breaths/minute (400 x 25 = 10,000)

	Vt	RR	MV
Healthy	500	20	10,000
Disease	400	25	10,000

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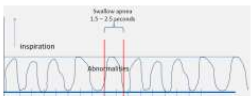

RESPIRATORY-SWALLOW COORDINATION

Respiratory Rate	Breath duration	Swallow duration
15	4	2
20	3	2
25	2.5	2
30	**2**	**2**
40	**1.5**	**2**

- **Inhale**
- **Begin Exhalation**
- **Close Airway**
- **Swallow**
- **Exhale**

(Matsuo & Palmer, 2009)

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RESPIRATORY-SWALLOW PATTERNS IN HEALTHY ADULTS

In healthy adults, swallowing is most frequently bracketed by exhalation

- Meta-analysis revealed 77.4% of swallows followed an E/E pattern. (Hopkins-Rossabi et al., 2019)

Why?

- Physiological advantage for anterior–superior movement of the hyolaryngeal complex, airway closure, and pharyngoesophageal segment opening
- Airway protective advantage- decreased risk of food or liquid inhalation

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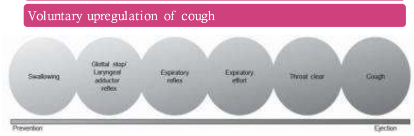
RELATIONSHIP BETWEEN COUGH AND SWALLOWING

- Protective mechanisms
- Modulated by sensory input
- Regulated by a "behavioral control assembly"
- Dystussia and dysphagia frequently co-occur
- Cough testing for dysphagia screening
- Voluntary upregulation of cough



(Troche et. al., 2014)

OBSTRUCTIVE VS. RESTRICTIVE LUNG DISEASE

- Restrictive: limits tidal volume
  - Interstitial lung disease, sarcoidosis, pneumoconiosis, neuromuscular diseases
- Obstructive: limits gas exchange
  - COPD, bronchiectasis, asthma

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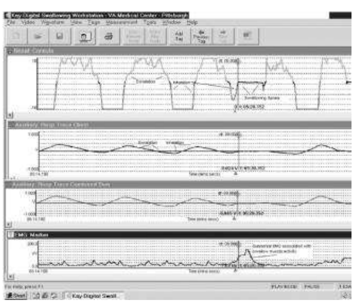
RESPIRATORY AND NEUROLOGICAL DISEASES THAT IMPACT RESPIRATORY, COUGH, AND SWALLOW FUNCTION

- Elderly Adults
- COPD
- ALS
- MS
- Stroke
- Dementia
- PD

RELATIONSHIP BETWEEN RESPIRATORY AND SWALLOW FUNCTION IN COPD

- **Respiratory-swallow incoordination**
  - Patients with moderate-severe COPD in a stable state demonstrate impaired respiratory-swallow patterns.
    - (Gross, Atwood, Ross, Olszewski, & Eichhorn, 2009; Nagami et al., 2017;Steidl et al., 2015)



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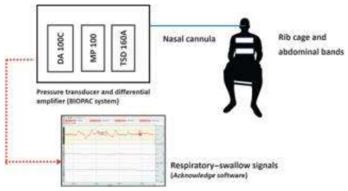
RELATIONSHIP BETWEEN RESPIRATORY AND SWALLOW FUNCTION IN ALS

- Preliminary data suggests that compared to healthy age-matched controls, people with ALS exhibit more frequent suboptimal respiratory patterns (non-exhale swallow exhale pattern).
- (Garand et. al, 2022)



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RELATIONSHIP BETWEEN RESPIRATORY AND SWALLOW FUNCTION IN HEAD AND NECK CANCER

- Head and neck cancer patients more frequently demonstrated swallowing during inspiratory flow than healthy adults and this was associated with penetration/aspiration and worse MBSImP scores (Brodsky et al., 2010)

	Respiratory phase pattern	
	E–E	Not E–E
Age-matched controls	72.5%	27.5%
Patients with cancer	37.5%	62.5%
SURG-XRT	36.4%	63.6%
CHEMO-XRT	38.9%	61.1%

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RELATIONSHIP BETWEEN RESPIRATORY AND SWALLOW FUNCTION IN PD

- Approximately 60% of swallows in individuals with PD are not bracketed by exhalation (Rangwala et al., 2023).

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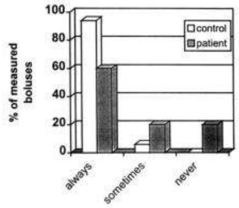
RELATIONSHIP BETWEEN RESPIRATORY AND SWALLOW FUNCTION IN PATIENTS POST-STROKE

- Post-stroke patients with dysphagia demonstrated post-swallow expiration less frequently than healthy adults for both water and yogurt boluses (Leslie et al., 2002).



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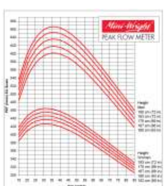
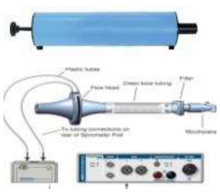
MEASURING PULMONARY FUNCTION: VOLUNTARY COUGH PEAK EXPIRATORY FLOW



- >160 L/min
- >270L/min
- (Cardoso et al., 2012)

VOLUNTARY COUGH SPIROMETRY



Cough Outcome:	Definition:
Inspiratory phase duration(s)	Time from onset of inspiration at 0L/s to the beginning of glottic closure or the start of the expiration onset
Inspiratory peak flow rate(L)	Peak inspiratory flow during the inspiratory phase
Compression phase duration(s)	Time to glottic opening; end of the inspiratory phase to the start of the expiratory phase
Expiratory rise time (s)	Time from the expiration phase to the peak of the expiratory flow
Peak expiratory flow rate(L)	Peak expiratory airflow during the expiratory phase of cough
Cough volume acceleration(L/s/s)	Expiratory peak flow/expiratory rise time

Watts et al., 2016

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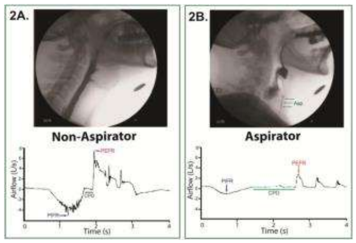
RELATIONSHIP BETWEEN COUGH AND SWALLOWING IN PALS

- Voluntary cough measures
  - Cough volume acceleration (91% sensitivity, 82% specificity)
  - Peak expiratory flow rate (83% sensitivity, 74% specificity)
  - Peak expiratory flow rise time (74% sensitivity, 78% specificity) (Plowman et al., 2016)



VOLUNTARY COUGH

Voluntary cough in patients post-stroke

- Differences in cough spirometry measures between patients who aspirated and those who didn't (Hammond et al., 2009; Hammond et al., 2001)

Voluntary cough in patients with PD

- Significant differences in peak expiratory flow rate, cough volume acceleration, and cough organization when comparing patients with PD with and without dysphagia (Hegland et al., 2014)
- Patients with PAS scores ≥2 have longer compression phase duration, longer peak expiratory rise times, lower peak expiratory flow rates, and lower cough volume acceleration (Pitts et al., 2008).

REFLEX COUGH

Rating	Intensity
0	No symptoms
0.5	Very, very slight urge
1	Very slight urge
2	Slight urge
3	Moderate urge
4	Somewhat severe urge
5	Severe urge
6	
7	Very severe urge
8	
9	Very, very severe urge
10	Maximal urge

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REFLEXIVE COUGH

Handheld cough testing in patients with PD
- Cut point of 42.5 L/min, 90.9% sensitivity, 80% specificity (Curtis et al., 2020)

Reflexive cough in patients with PD using a fog stimulant
- 77.78% sensitivity, 90.9% specificity for discriminating between patients with PD with and without dysphagia (Hegland et al., 2016)

Heterogenous groups of patients with dysphagia using citric acid
- Time to first cough ≤60s, 81% sensitivity, 65% specificity (Sato et al., 2012)

Patients with dysphagia undergoing instrumental evaluations
- 71% sensitivity, 60% specificity (Miles et al., 2013)

RESPIRATORY RATE, RESPIRATORY-SWALLOW PATTERNS

- Resting respiratory rate
- Active respiratory rate
- Direction of airflow

(Steele & Cichero, 2014).

MEASURING PULMONARY FUNCTION: MAXIMUM EXPIRATORY/INSPIRATORY PRESSURE

- Measurement of the **strength** of the **respiratory muscles**
- Patient exhales/inhales as strongly as possible against mouthpiece

MEP AND MIP NORMATIVE DATA

Age (years)	Males (N = 50)			Females (N = 50)		
	MIP (cmH_2O)	MEP (cmH_2O)	MVV (l)	MIP (cmH_2O)	MEP (cmH_2O)	MVV (l)
20-29	129.3 ± 17.6**	147.3 ± 11.0**	166.9 ± 20.2**	101.6 ± 13.1*	114.1 ± 14.8*	125.5 ± 13.3*
30-39	136.1 ± 22.0*	140.3 ± 21.7*	170.2 ± 29.7*	91.5 ± 10.1	100.6 ± 12.1	123.6 ± 11.2
40-49	115.8 ± 87.0*	126.3 ± 18.0*	151.2 ± 34.4*	87.0 ± 9.1	85.4 ± 13.6	115.5 ± 8.4
50-59	118.1 ± 17.6*	114.7 ± 6.9*	132.4 ± 27.4*	79.3 ± 9.5	83.0 ± 6.2	105.9 ± 20.8
60-69	100.0 ± 10.6*	111.2 ± 10.9*	138.8 ± 22.0*	85.3 ± 5.5	75.6 ± 10.7	95.7 ± 19.3
70-80	92.8 ± 72.8*	111.5 ± 21.0*	108.0 ± 25.6	72.7 ± 3.9	69.6 ± 6.7	93.5 ± 18.9

EXPIRATORY MUSCLE STRENGTH TRAINING

4-weeks of EMST in patients with PD
- Improvement in cough effectiveness, PAS scores, hyolaryngeal excursion (Pitts et al., 2009; Troche et al., 2010)

4-5 weeks of EMST in patients post-stroke
- Improvements in maximum expiratory pressure, cough peak expiratory flow, cough volume acceleration, reflexive urge to cough responses, and swallowing safety (Hegland et al., 2016; Park et al., 2016)

8 weeks of EMST in head and neck cancer patients with chronic radiation-associated dysphagia
- Improvements in expiratory pressure generation, swallowing safety, and swallowing-related quality of life (Hutcheson et al., 2018)

5 weeks-24 months of RST in patients with ALS
- Improvements in pulmonary, cough, and swallow function (Plowman et al., 2016; Tabor-Gray et al., 2016; Robison et al., 2018; Plowman et al., 2019)

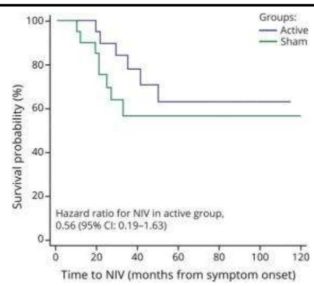
INSPIRATORY MUSCLE STRENGTH TRAINING

IMST in patients with ALS (varying lengths)
- Attenuated decline/improvement in pulmonary function, increased survival (Pinto et al., 2012; Pinto et al., 2013)

8-12 weeks of IMST in patients with PD
- Improvements in maximum inspiratory pressure, inspiratory muscle endurance, dyspnea, subglottic pressure, maximum phonation time (Inzelberg et al., 2005; Reyes et al., 2019; Reyes et al., 2018)

COMBINED RESPIRATORY STRENGTH TRAINING IN ALS

- Significant improvements in MEP and MIP, and cough peak inspiratory flow.
- Sham group had two times faster decline rate than active RST group based on ALSFRS-R scores at 12-month time point. (Plowman et al., 2023)



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RESPIRATORY-SWALLOW COORDINATION TRAINING: HEAD AND NECK CANCER PATIENTS

- 30 patients with head and neck cancer
- Outcome measures
  - Videofluoroscopy (PAS and MBSImP scores)
  - MD Anderson Dysphagia Inventory Scores
- 2 training sessions for 4-8 weeks for 1 hour (Martin-Harris et al., 2015)

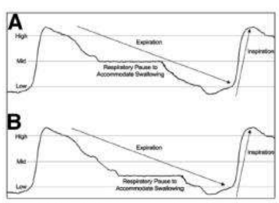

Fig 1 Initiation of the pharyngeal swallow during expiration at midvolume (A) and mid to low volume (B). The swallow occurs as respiration ceases (respiratory pause).

(Martin-Harris et al., 2015)

RESPIRATORY-SWALLOW COORDINATION TRAINING: HEAD AND NECK CANCER PATIENTS

Improvements in:

- PAS Scores
- Laryngeal vestibule closure
- Tongue base retraction
- Pharyngeal residue

RESPIRATORY-SWALLOW COORDINATION TRAINING AND VOLUNTARY COUGH SKILL TRAINING: PD

Case study in an 81-year-old patient with PD (8.5 years since dx, 2 years severe dysphagia)

Post respiratory-swallow coordination training

- Increase in exhale-swallow-exhale pattern
- Decrease in lung-volume initiation and swallow apnea duration
- Improvements in PAS scores, pharyngeal residue, DIGEST scores, and SWAL-QOL scores

Post voluntary cough skill training

- Increase in peak expiratory flow rate for single and sequential voluntary cough and reflexive cough

(Curtis et al., 2020)

RESPIRATORY-SWALLOW COORDINATION TRAINING+ EMST IN ALS: A CASE SERIES

- EMST+RST and EMST alone led to improvements and/or slower decline rates for PALS in pulmonary measures, the FOIS, EAT-10, SWAL-QOL, and diaphragm thickness following intervention/maintenance compared to no intervention. (Donohue & Coyle, 2020)

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COUGH MODULATION

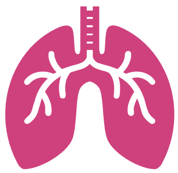
Modulation of reflexive cough in healthy adults

(Hegland et al., 2012).

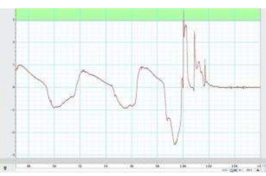
20 healthy adults

- Measured cough airflow and sEMG of expiratory muscles during 4 conditions (baseline, small cough, long cough, and no cough)
- Random presentations of capsaicin and control solution
- Non-cough behaviors during suppression included: throat clear, breathholding, expiratory efforts, swallowing
- Small cough: Increased compression phase duration, decreased post-peak phase duration, and decreased cough volume acceleration.
- Long cough: Increased post-peak phase duration, increased post-peak phase integrated area, longer sEMG duration

COUGH UP-REGULATION



- Voluntary and reflexive cough upregulation in healthy adults and patients with PD (Brandimore, Hegland, Okun, Davenport, & Troche, 2017).
  - 28 healthy age-matched adults
  - 16 patients with PD
  - Examined voluntary and reflexive cough under 2 conditions: baseline and cued
  - Cough peak expiratory airflow rate and cough expired volume (both voluntary and reflexive cough) were greater during cued conditions.



SENSORIMOTOR TRAINING IN AIRWAY PROTECTION SMTAP IN PSP

- Mean peak expiratory flow rate increased across smTAP trials, demonstrating the ability to upregulate cough in PSP. (Borders et al., 2022)

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COMPARING EMST AND SMTAP IN PD

- MEP, voluntary PEFR, improved pre- to post-treatment for EMST and smTAP.
- Reflex cough PEFR, reflex cough expired volume, and urge to cough improved for the smTAP group only. (Troche et al., 2023)

	EMST	smTAP
Primary Tx Target	Maximum Expiratory Pressure (MEP)	Voluntary Cough Peak Expiratory Flow Rate (PEFR)
Type of Training	Primarily strength-based	Primarily skill-based
Treatment Dose	5 sets of 5 breaths = 25 breaths	5 sets of 5 coughs = 25 coughs
Treatment Intensity	EMST @ 75% MEP	Voluntary coughs @ 25% above PEFR
Time Period	5 days a week – with clinician once per week and four days of independent home practice (both tx)	
Tx with Clinician	25 repetitions of EMST	25 coughs via spirometry with sub-threshold capsaicin and real-time visual biofeedback
Home Program	25 repetitions of EMST (a)	25 coughs using a handheld peak flow meter (b)

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SUMMARY & SYNTHESIS

- Pulmonary, cough, and swallow function are highly integrated.
- Co-occurring impairments frequently occur in patients with underlying respiratory/neurological diseases.
- Dysphagia management involves integration of multiple subsystems for effective assessment/treatment.

QUESTIONS?

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