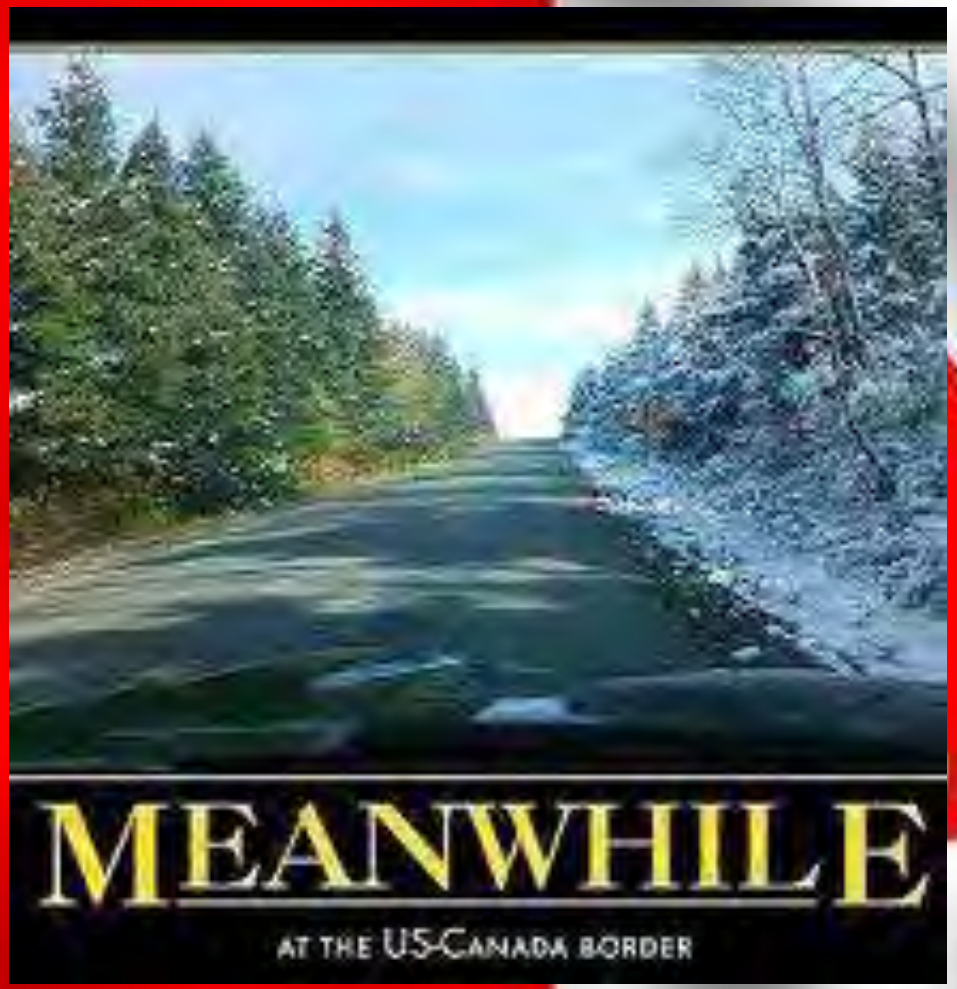
Polly Ubben, M.A., CCC-SLP, FNIP

Vocal strengthening

Disclosures

- Nothing to disclose



Polly

Overview: Vocal strengthening and its importance.

Why Vocal Strengthening?

- Anatomy & Physiology
- Etiology of vocal weakness
- Exercise Physiology
- Vocal Exercises For Different Needs
- Respiratory/Laryngeal coordination and Strengthening
- Avoiding Vocal Strain & Vocal Fatigue
- Take-aways

Strength Programs With Skeletal Muscle

Athletic performance:

- physiologic elements
- elements of performance

Vocal performance:

- occupational voice use has highly variable needs

Voice therapy treatment protocols have been lacking when accounting for these variables r/t **dosing and calibrating to specific environmental demands**

For Superior Voice Treatment

we need to account for adaptability of tissue, types of muscle fibers, neuromuscular aspects and how energy is used in specific & individual cases

“The body wants to work efficiently & to that end, muscles adapt in times of physical challenge, upregulating various mechanisms to help the muscle work more efficiently”…The opposite is also true, after weeks or months of vocal rest, the vocal folds lose **“match fitness”.** A loss of acoustic tone, laryngeal agility & general lack of vocal stamina.
(Mary Sandage)

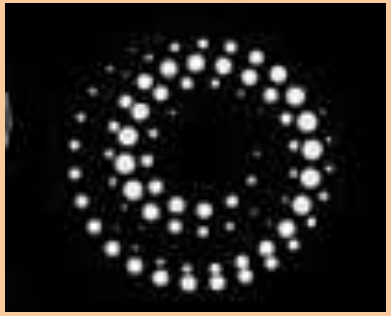
Laryngeal muscle: skeletal, so why so long to obtain information about how exercise physiology is applied to vocal strengthening?

- ***COMPLEX*** *interconnected dynamic* between the environment and ***subsystems***. NON-LINEAR, SYNERGISTIC.

- We also have the **QUALITATIVE** ability to produce desired quality, volume, range, & sustained length of production, & stamina for repeated productions.

Vocal Activation Overview:

Cyclical Coordination of muscle activation in each of 3 subsystems involved in voice use (Aaron Johnson and Mary Sandage, 2019)



- **Coordinate** adequate inhalation for the specific task
- **Set** initial muscle positions
- **Rapidly adjust** the 3 subsystems through the task for respiratory, phonatory and articulatory demands, while modulation of pitch & intensity are adjusted.

Repeats the cycle for each utterance at times immediately and other times with turn taking depending on the context.

Muscle Activation: Speech/Singing

Red= Respiratory

Green= Phonatory

Blue= Resonance

(Johnson & Sandage, 2019)

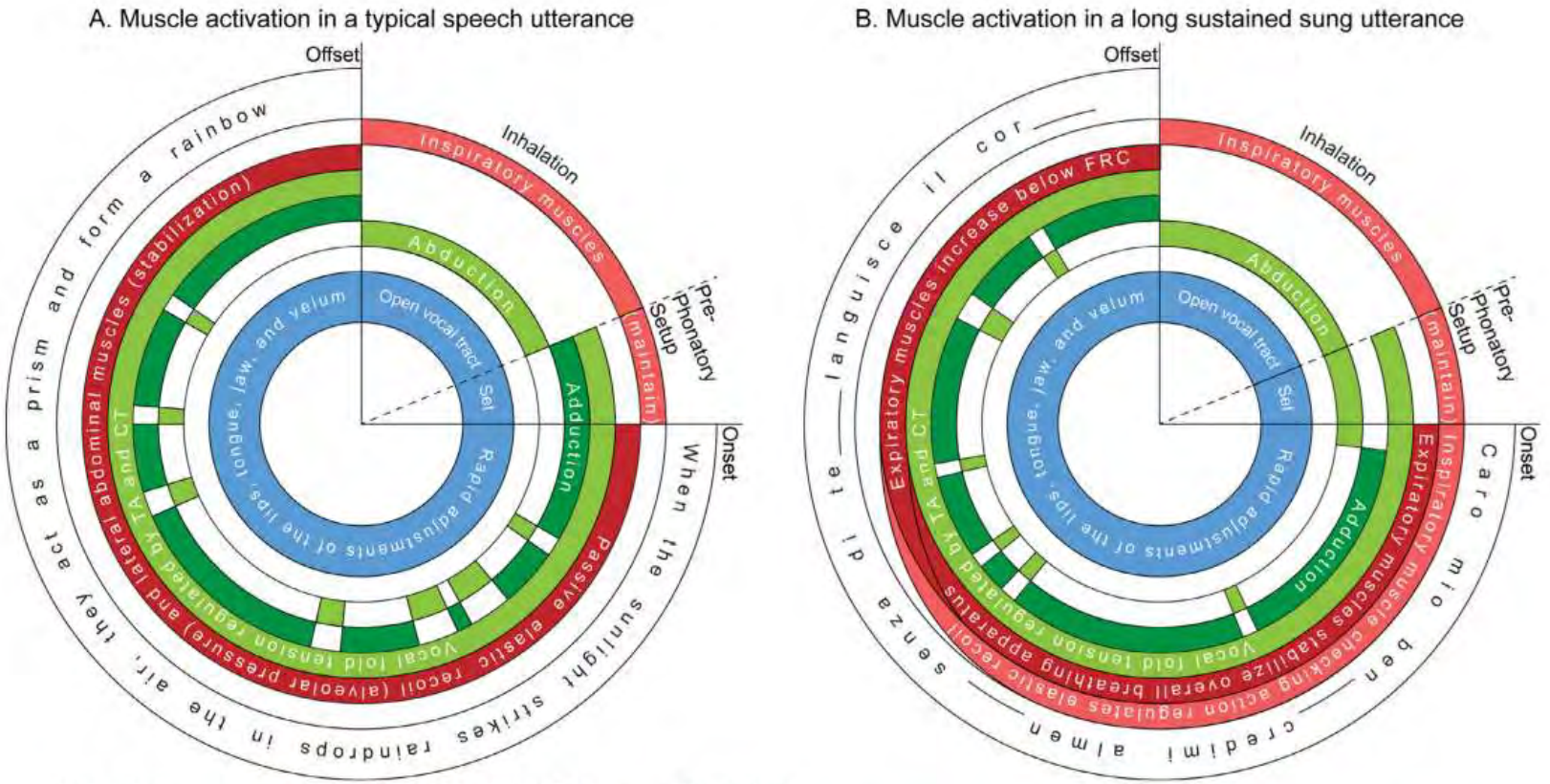


FIGURE 2. Model of neuromuscular coordination during vocalization of (A) a spoken utterance and (B) a sustained sung phrase.

We understand & use **skill acquisition** in our voice therapy protocols but we haven't been paying attention to:

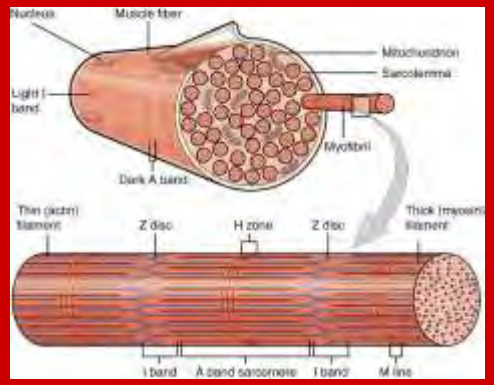
"up-regulation"

- build fatigue resistance
- prevent injury
- optimize vocal recovery

Anatomy & Physiology

The anatomy of a muscle:

Muscle fibers-> myofibrils(organized bundles of sarcomeres)->sarcomeres->thin filaments of actin and myosin



Nerve activation:

- an electrical impulse->
- axon->
- release of acetylcholine into the synaptic cleft->
- excites or inhibits muscle cell activity->
- if activating, Ca+ released then resequesters working on the proteins in the muscle to get a contra

Decide to sing a “C” …

- Efferent nerve—>
- Afferent Nerve “job done”-->
- 3rd set of neurons integrates but that’s not all.

There is amazing gradation by our transmitters to allowdosing for specific musical notes to withi ⅛ of a tone.

<u>This is comparable to an astronaut steering a space ship to w/in 1/1,000 of a degree on a charted path (Arbitol, J. 2005).</u>

This tone adjustment is all done within a few hundredths of a msec.

Skeletal Muscle Fiber Types

Type I Fibers:

- Slow twitch.
- Maintain posture.
- Fatigue resistant.
- Rely on oxidative phosphorylation **ENDURANCE** (aerobic)

Skeletal Muscle Fiber Types Cont'd

Type IIx (2B) Fibers:

- Fast twitch BUT fatigable.
- Quick, **powerful**, high intensity work.
- Use glycolysis and oxidative phosphorylation. (anaerobic)
- Initiates muscle activity

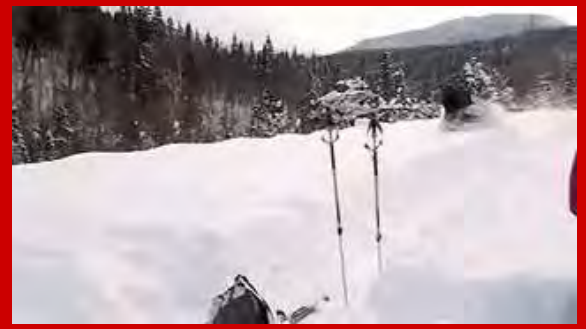
Most people are 50/50 type I & type II.

Elite endurance athletes >Type I,

Elite sprinters >Type IIx

Bioenergetics-Producing Fuel For Muscles:

3 simple physiologic methods producing adenosine triphosphate (ATP),



1) "Sprinters"-Use a lot of energy-anaerobic

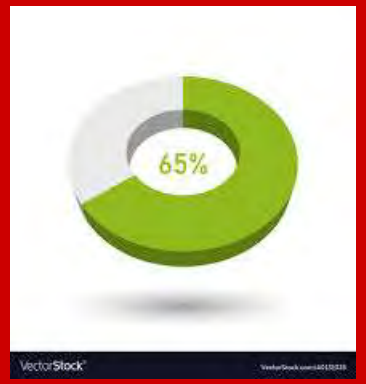
- Immediate Energy System (1st min. of ex)
- Glycolysis (using circulating glucose, several min./inefficient)

2)"Endurance Runners"-Fatigue resistant-aerobic

- Oxidative Phosphorylation(takes a few minutes to kick in), used AFTER 2-3 minutes. Use O2/ efficient.

Human Larynx Muscle Fibers:

Cadaver studies:



- Most intrinsic laryngeal muscles rely most on **anaerobic** energy. about **65% are Type IIx(2B)** WHY? **AIRWAY PROTECTIVE** —----->
- about **35% are Type I** (Primarily the PCA). WHY?**AIRWAY PATENCY**

Fiber predominance & muscle use in the larynx cont'd:

Most voiced intervals= only 3 seconds (Smith, et al, 2017).

Theoretical Clinical Applicability (Johnson & Sandage, 2021) :

- **Occupational voice use** w/accumulated daily voice dosing over full day/week **bursts** and **stamina** elements.

Target **up-regulation** of **fatigue resistant** & **rapid anaerobic recovery** in **connected speech tasks.**

- **Singers:** Consider number of sets/style

Fatigue

- **COMPLEX:**Perceived vs. physiologic, male vs. female
- **Tools** from ongoing research: **Vocal Fatigue Index (VFI),** Glottal Function Index (GFI), **Evaluation for the Ability to Sing Easily (EASE)**

Difficult to measure

Fatigue with Conversation

"Vocal Dosing" research (Smith, Sandage et al.)- 3 sec. bursts (immediate ballistic energy) but…c**lassroom teachers do this 1,000x/day(endurance based)**. Duration of phonation helps train for this.

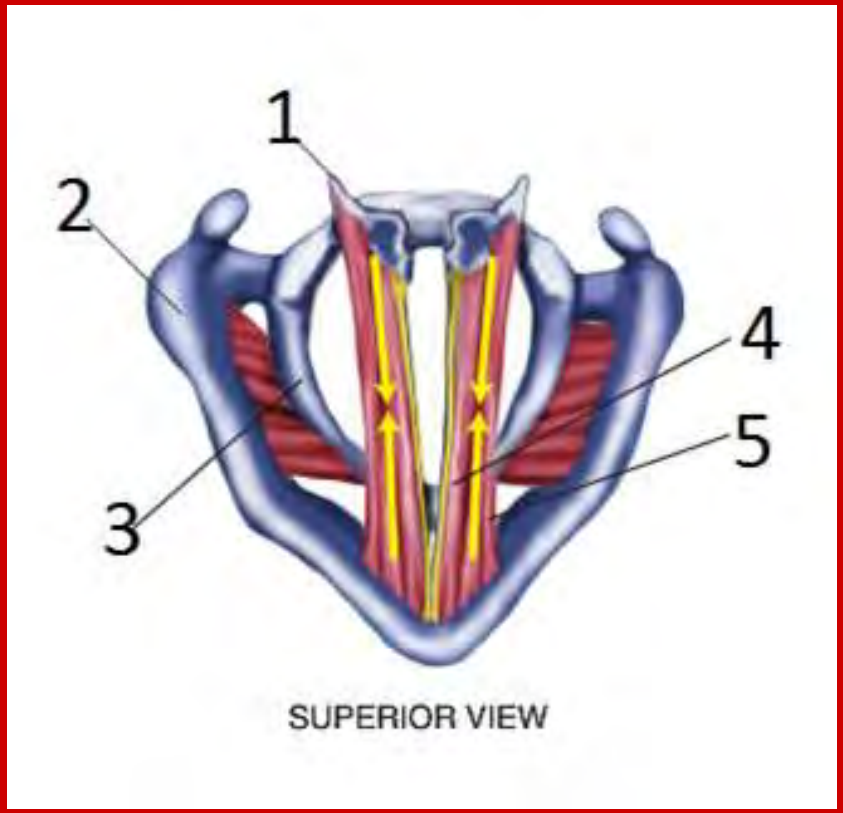
- Low-loading cycle w/ conversation does not fatigue the muscles

BUT if i**ntensity or frequency is increased**, neuromuscular load also increases & fatigue sets in.

Muscles of the Larynx

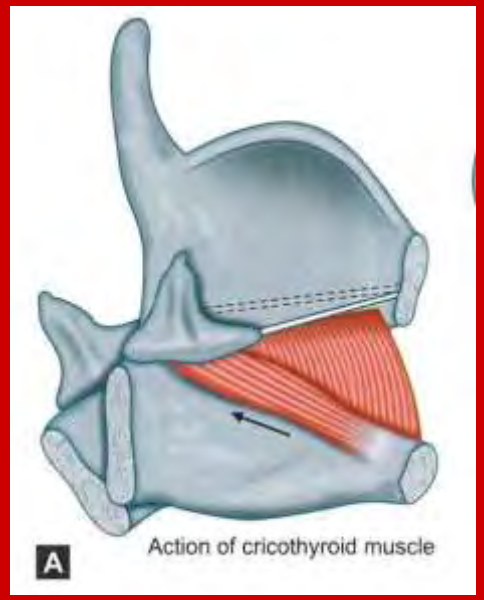
Thyroarytenoid Muscle:

- **Shortening & relaxing** VF's. **lowering** pitch, (even in low volume falsetto range).
- **Softening** voice by relaxing vocal ligament.
- **Widening the laryngeal inlet**
- Thought to **assist the CT w/ very high pitch productions**



Internal Muscles of the Larynx

Cricothyroid (CT)



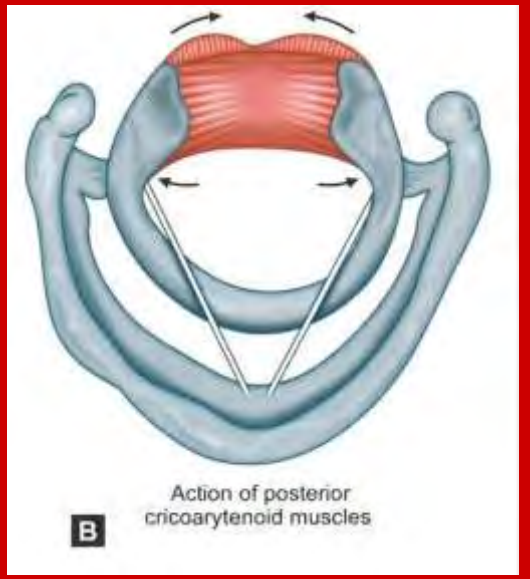
- **Lengthens & tenses** t VF's for higher pitches & may assist in pitch lowering adjustments
- **Vibratory phase symmetry, acoustic periodicity, shifting voiceless to voiced** (Orestes, M. & Chhetri, D.)
- Innervated by the SLN branch of the Vagus Nerve.

Clinical applicability:

- Can act as an **accessory adductor** or an **accessory abductor.**

Posterior Cricoarytenoid Muscle (PCA)

- Acts to ABduct the VF's
- Has the most **Type I muscle fibers(endurance)**



Clinical applicability ideas:

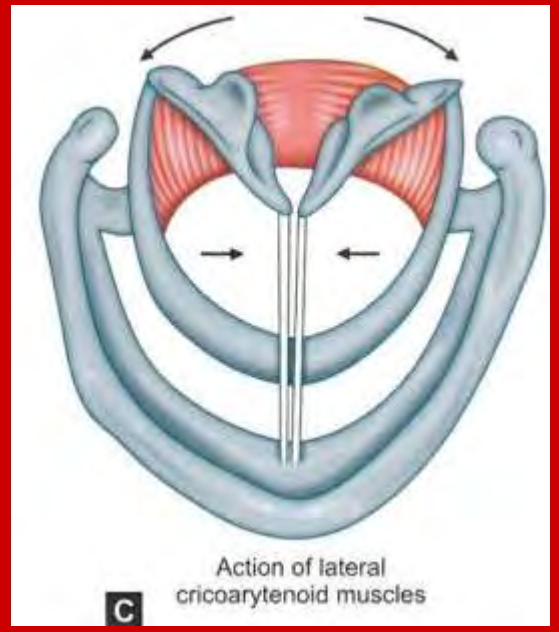
Assists breathing & activated w/ a sniff for inducible laryngeal obstruction pts (ILO).
Can also be used with muscle tension dysphagia & Adductor Spasmodic Dysphonia.

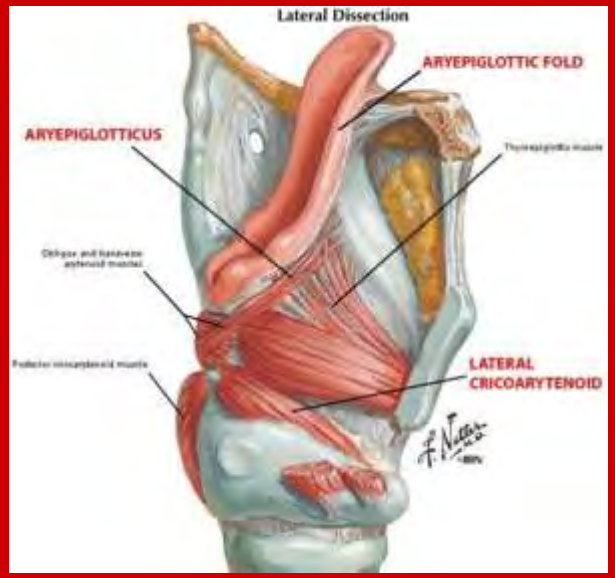
Lateral Cricoarytenoid (LCA)

- Acts to **ADDuct/close VFs** during swallowing & voice use.
  Primary antagonist to the PCA.
  Activation increases w/higher subglottic pressures.

Clinical applicability thought:

People who develop granulomas tend to be LCA dominant. (vocal press)

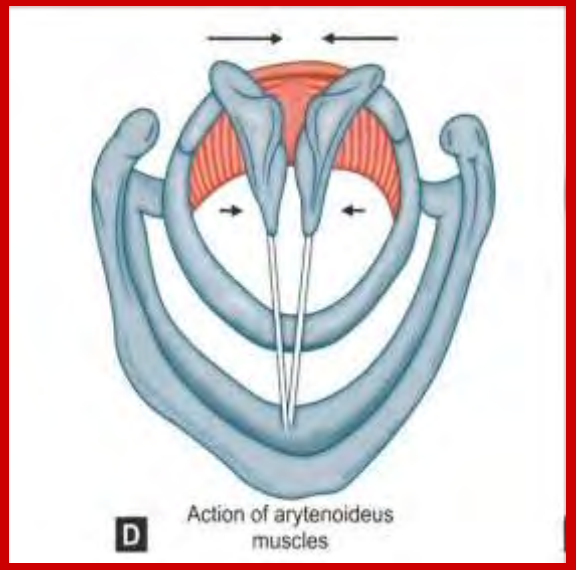




Internal Muscles of the Larynx

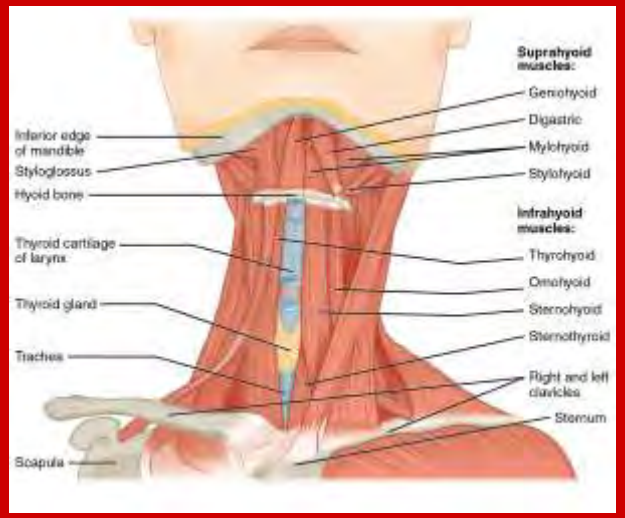
Interarytenoid (Transverse) Muscles:

- **ADDuct VF's** bringing vocal processes of arytenoid cartilages together for voice & swallowing.
- The only unpaired muscle of the larynx

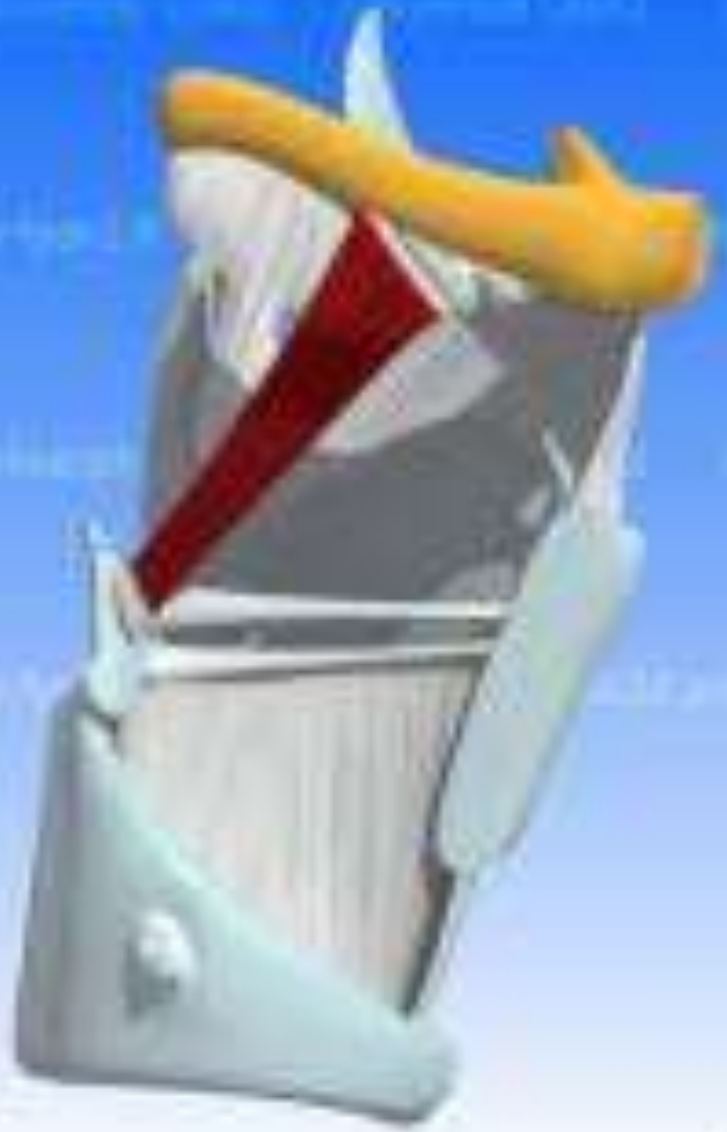


External Muscles of the Larynx

Thyrohyoid, Omohyoid, Sternothyroid & Sternohyoid Muscles



- Infrahyoid muscle group: depress hyoid bone & lift thyroid cartilage in swallowing & high pitch productions



Ary-epiglottic muscles:
lower the epiglottis

Muscles of the Vocal Tract

Shape & alter length of vocal tract & resonating spaces.
Resonance & articulation consist of **rapid fine motor adjustments**.
So strength?…

Tongue, Facial Muscles: Per square inch the tongue is the strongest muscle in the body. No data on strength during running speech but **even swallows use only ⅓ to ½ of max strength**.

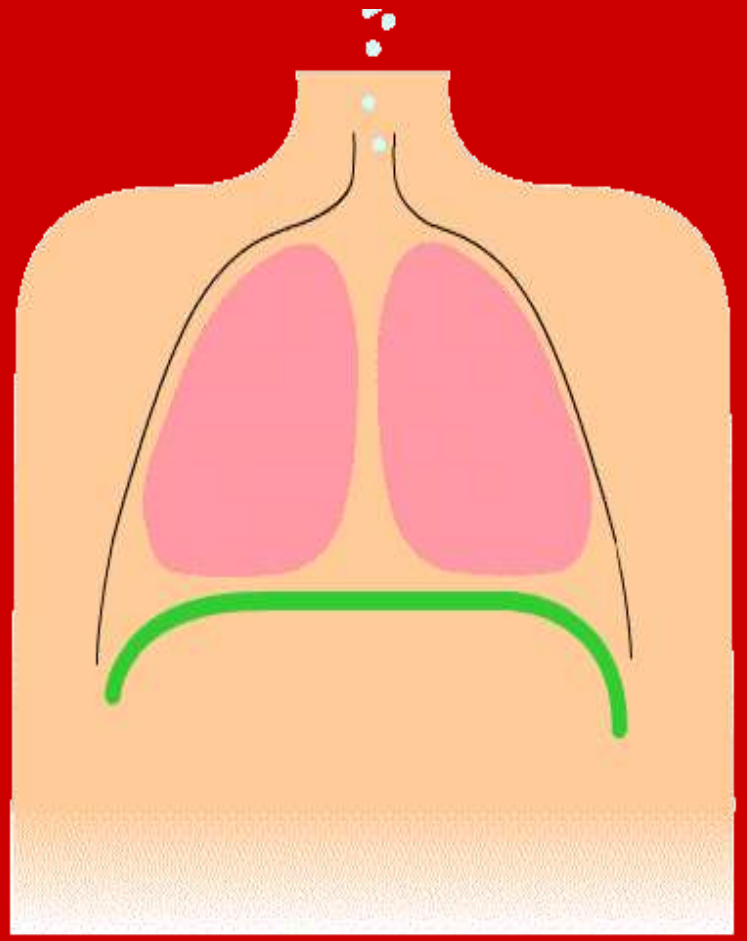
Research: ***Endurance athletes*** *found to have more endurance in tongue push whereas* ***weightlifters*** *had more strength*

Respiratory Muscles

3 Groups:
Diaphragm, rib cage muscles & abdominals

- **Diaphragm:** “Flow generator” during active periods. Shortens rather than generating pressures.

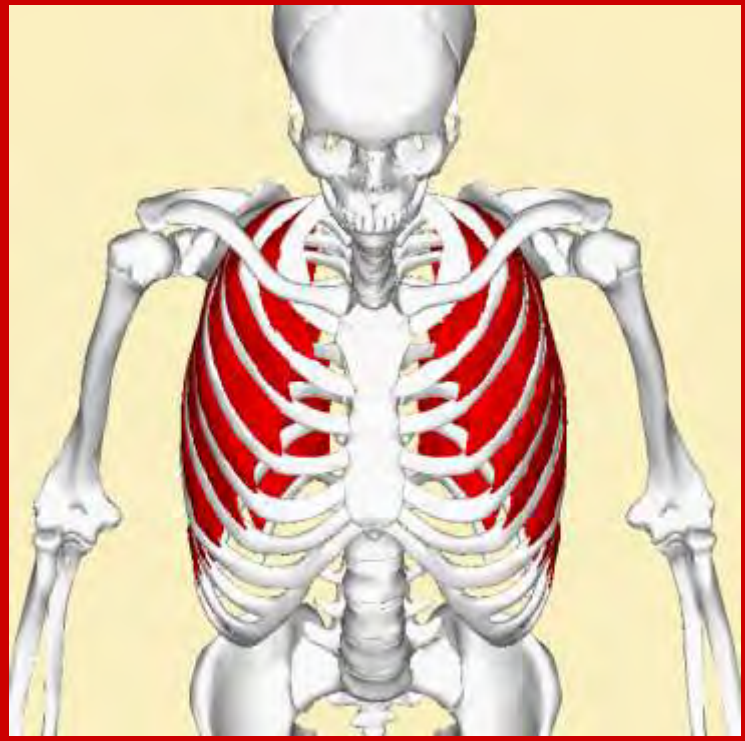
- During rest, no exhalatory muscles are used (passive)



Intercostals: Pressure generators

External-expands ribcage & sternum out & up

Internal-push the rib cage down & **the most important for speech & singing.**

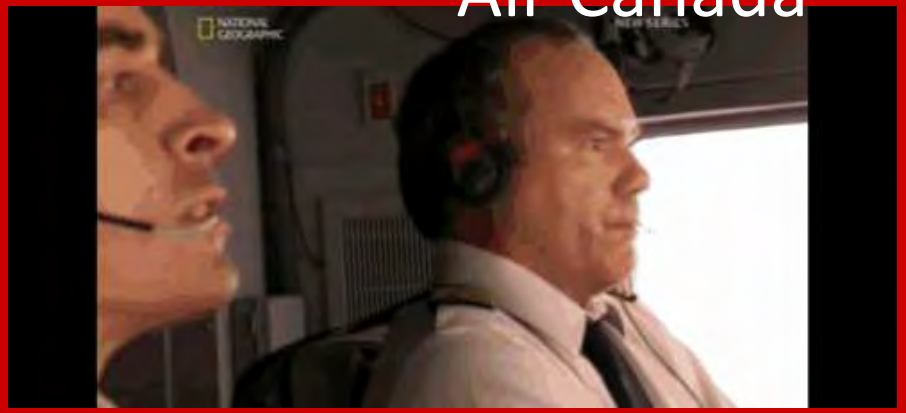


Abdominal Muscles: Pressure generators

Used during **active exhalation w/voice, singing & pulmonary clearance**

Muscles of the Respiratory System Cont'd

Air Canada



Active max respiratory pressures in healthy

- males=233 cm H20,
- females=152 cm H20

- Vocal production takes very little respiratory strength (5%)
  - **4-6 cm H2O for VF vibration & 10-25 cm H20 for loud speech or singing though can go higher**
  - Endurance & coordination are more relevant targets

Respiratory muscle strength training (RMST) which includes EMST & IMST

- Mismatch of specificity to voice use so, crucial? Unkown.
- Mounting evidence of success strengthening respiratory muscles in pt's w/conditions limiting respiratory (COPD etc)
- so, **as a subsystem of vocal production**, may help those *w/ respiratory conditions.*
- IMST may be beneficial with EILO
- cRMST (The Breather)works on cycles of expiratory & inspiratory flow & is NOT a threshold device.

- More relevance targeting ENDURANCE for extended exhalation for voice.

Postural Muscles:

Correct **‘Form’** can be limited by postural deviations:

- **Hip/pelvis** flexion pulls ribcage down.
- **Scalenes** tighten. Chronic shortening & flexion of rectus abdominis strains entire body including the cervical spine w/compensation.
- Prolonged sitting (Robinson et al.) = core muscle changes w/head forward posture ->weak deep neck flexors & tight neck extensors ->weak glutes & rotated twisted spine.
- Postural changes at **styloid process** anteriorly ->adaptive shortening of stylohyoid, **elevating larynx, resisting forward translation of hyoid & thyroid** in singing.

Physiologic Considerations of Laryngeal Muscles

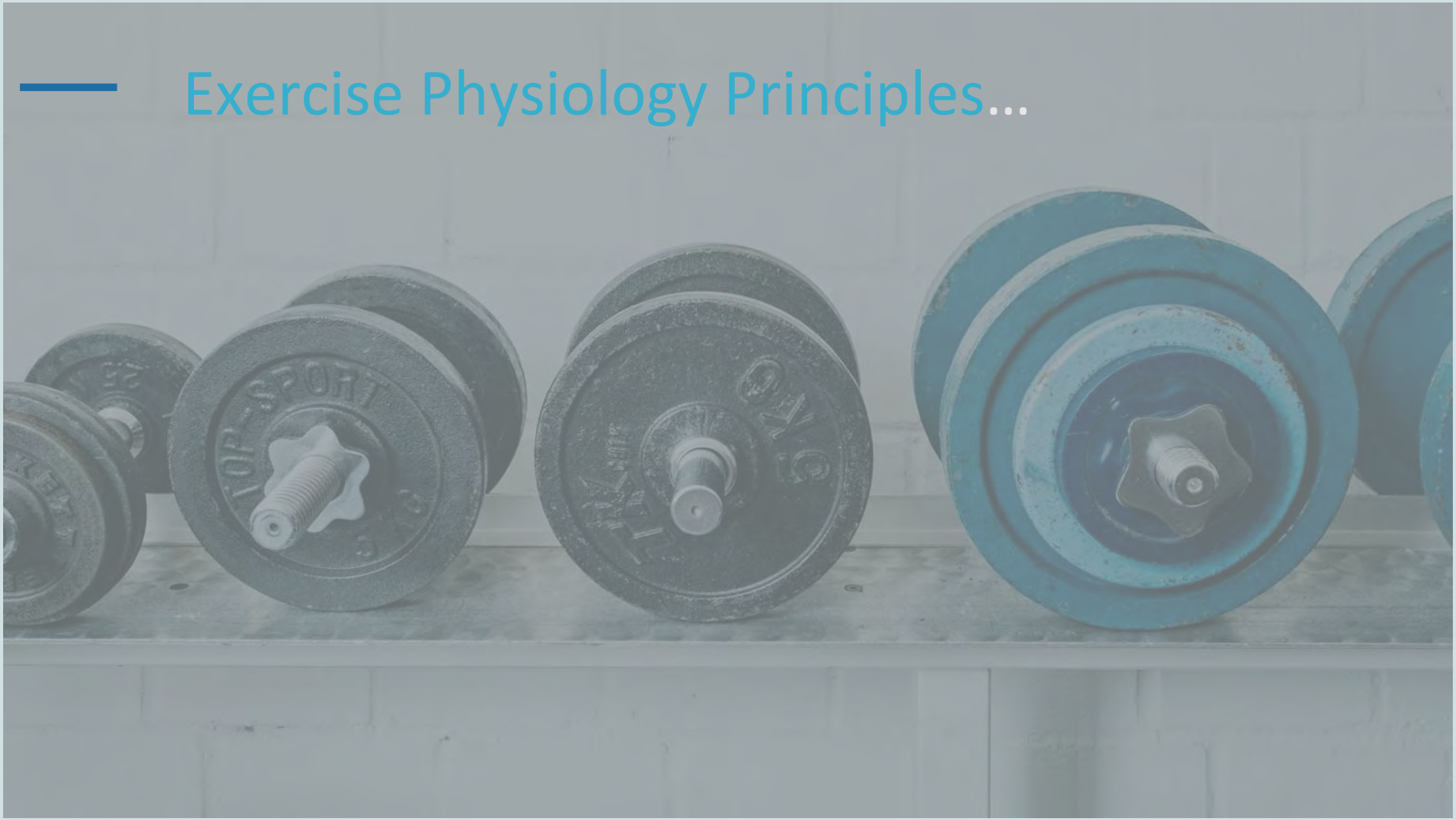
- Contraction Types:
  - **Sustained** contraction
  - **Dynamic** contraction-tiny, rapidly moving muscles-***actually more phenotypical of skeletal extraocular eye muscles than limb muscle).***

- Contraction maximums in non-voiced tasks are much higher than that used in voice production.

So why talk strengthening?

Vocal Strengthening engages **subsystems** for functional strength gain

Exercise Physiology Principles…



Skeletal Muscles Adapt W/ Exercise “Use It or Lose It”

3 Changes:

- **Hypertrophy**-Size, and vol of. capillaries, mitochondria
- **Neurologic Change** right type & # of muscle fibers Powers & Howley (2012) found this change makes up >80% of physical change in the first 4-5 weeks of exercise.
- **Metabolic Change-** capillary and mitochondrial density increase offloading of O2

Muscle Training:
Specific Adaptation to Imposed Demand *(SAID)*

- **Specificity-**recruitment specific motor units w/appropriate forces & velocities for specific tasks
- **Overload-**work beyond capacity - ***intensity, duration, frequency,***
- **Reversibility**-gains lost quickly if overload removed

Exercise Programming

- **Progression**-intensity & volume gradually increased
- **Adaptation**-body adapts to exercise & stresses becoming more efficient w/ flexibility & strength
- **Maintenance**-once a level is achieved it needs to be maintained
- **Diminishing Returns**-w/more training, improvement slows
- **Periodization**-vary exercise over time to enhance adaptations & prevent overtraining

Muscle Detraining/Disuse in the Larynx

Reduction in exercise= faster protein degradation.

- The larynx would NEVER be fully inert
- W/decline in intensity, endurance, power & versatility, loss of mass, fiber conversion, decrease in force contraction, & decreased resting potential in neuromuscular junctions.

Research w/anecdotal evidence suggests reduction in vocal durability after **voice breaks** of 2 weeks+.

Etiology of vocal weakness:

- Disuse atrophy
- Personality, anxiety/depression/PTSD
- Histology of aging
- Neurologic conditions
- VF paralysis (tumor, injury, viral, neural)
- Medications: muscle relaxants, sedatives, some antidepressants (*tricyclic and SSI)*), beta-blockers, corticosteroids, antipsychotic medications, anticonvulsants, statins

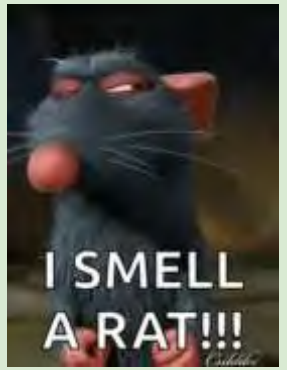
Personality influence: **“Driven” people** can have tightly bound lowered larynx, **high anxiety people**=high larynx.

- Narrowing of the cricothyroid visor-> decreased ROM from glottal fry to falsetto
- Discomfort-tension-> pain->reinforces holding pattern->imbalance
- CLDM only successful if postural changes are made. Referral to P.T.

Aging Impact on Laryngeal Strength

- Muscle contraction forces slow down (McMullen & Andrade, 2006)
- Loss of neuromuscular junctions w/regression of nerve terminals & postsynaptic acetylcholine receptors empty.
- Shift of reliance to glycolytic metabolism
- Rat studies reveal blood flow alterations & neuromuscular junction changes in the TAs

(Connor, Suzuki, et al. 2022)



A 2011 study in the *Journal Otolaryngology-Head Neck Surgery* indicated that about **30% of the population** experiences a decrease in QOL, endorses a barrier to social interaction & develops resultant depression & anxiety associated with **presbyphonia.**

Presbyphonia (Cont'd)

- Not just change d/t sarcopenia, but also r/t >TA use & possible shifting of muscle dominance to CT
- Thus high, "thin" voice production.
- There is also corresponding reduction in respiratory strength w/ pulmonary elasticity & tissue stiffening in vibrating portion of the VF's.

Benefits of exercise & strength training on aging voice EMERGING!

- Even VERY OLD muscle (> 90 years) can be strengthened (Lieber, 2010).

- **Strength exercises engage the other subsystems so for aging/ weak voices they are beneficial:**

- Phonation Resistance Training Exercises (PhoRTE).
- LSVT LOUD
- **Stemple's Vocal Function Exercises (VFE)**

Voice (Subsystem) Exercises

Aging & Weak Laryngeal Systems:

- All incorporate at least 1 **maximal task** (phonation time, frequency or intensity)
- They do NOT reach max levels of vegetative function, **BUT,** use sub-systems & tasks at higher activity levels than daily voice use. **Beyond "Match Fitness"**

Joseph Stemple's Vocal Function Exercises:

- Systematic, described in theory as P.T.
- Strengthens & coordinates the vocal mechanism using **3 subsystems.**

1) Warm-up:
2) Stretching VF's
3) Contracting VF's
4) Power adductory

Do 2x each, 2x/day. Each exercise lasts 2 minutes. Why? it it the length of time needed for fibers to change.

VF Atrophy W/Aging: and Push/Pull Ex's

- **Form** (unloading/balance) and **strengthening**/adaptation
- Pushing/pulling or glottic attack in very brief pulses from diaphragm

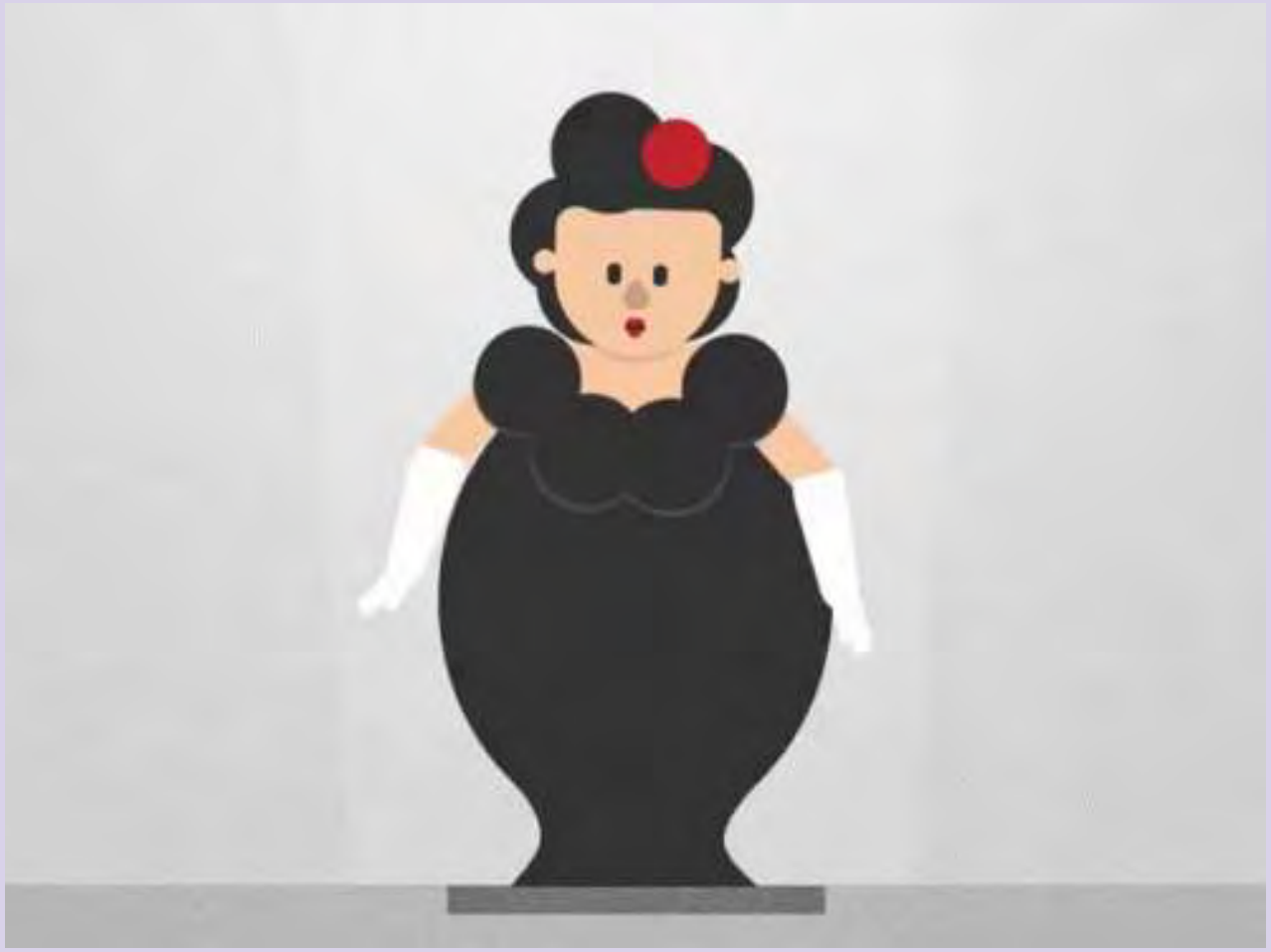
Pull up on seat of chair and use counting or syllables of about 300-500 msec. Any longer length pulls result in supraglottic hyperfunction. Increased MPT.
(Fujimaki et al, 2016)

Consider Crescendos:

- breath **flow control**
- **precision** of VF closure as subglottal pressures increase
- **fine motor** control between the subsystems
- **versatility** layer w/ strengthening,
- hyperfunctional voices: as next step post unloading to build stamina
- aging

But…remember **FORM**!!

Singers and “Match Fitness”



First, To Warm up Singer or Not…

From exercise physiology literature:

1) Increases blood flow and O2 delivery to skeletal muscles
2) Increases muscle temperature for increased muscle enzyme activity
3) Increases flexibility and ROM in joints and muscles.

Warm ups should be 10-20 min for singers

Leave vocal sirens to the end of warm-ups

Singers and “Talkers” Need to Know When Not To Use Voice

Marathon-

Don’t overspend your vocal budget!

Vocal rest is a good thing, vocal hibernation is NOT.

Singers & Vocal Strengthening

- Build *slowly* over time
- Motor learning NOT motor performance
- Their feedback first. (we talk too much)
- Start with 20 min. 1x/day. Ex. no less than 3x/week
- Add 5 min./session q 2 weeks up to 1 hour

Rule of Thumb: every min. of vocal practice= 2 min. of performance

Genre, songs and age of singer will impact this. (Robinson, D.)

Vocal Athletes

-Reduce fatigue

-Improve vocal fitness

-Healthy sleep/diet

Individual Application of Exercises:

Program for individual vocal health/fitness

- Move around the keyboard
- Vary what you do
- Focus on what you see & build ex's.
- Set parameters of vocal mileage
- High load max
- Coordinate vocal strengthening with their **singing voice coach**

10 Tips For Powerful Vocal Exercise (Dan K. Robinson)

- Schedule
- Dedicated Space
- Set Goals
- “Blueprint” practice
- Start Over Every Day
- Warm up 15-20 min.
- Set Time Limit
- Manageable Chunks-isolate dynamics
- Illness Plan-research
- Memorize/Review

Genre should be considered in specificity

- Don’t use classical techniques with contemporary singers.

Classical Singers

Contemporary Singers

- Typically use < **volumetric pressures** so have **heightened awareness of airflow** at laryngeal level Sustaining notes.
- Focused on **lengthening** & structuring around vowels.
- CT >active, **work out high to low**

- Activate **TA & vocalis more** in the "chest voice"
- Focused around **shortening** & is **consonant driven** providing the "pulse/kick" to establish rhythmic style.
- TA >active so, **work out low to high**

So Let's Look At Registration

Whistle

CT fully engaged,
TA fully disengaged

Flute/Falsetto

Upper

Lower

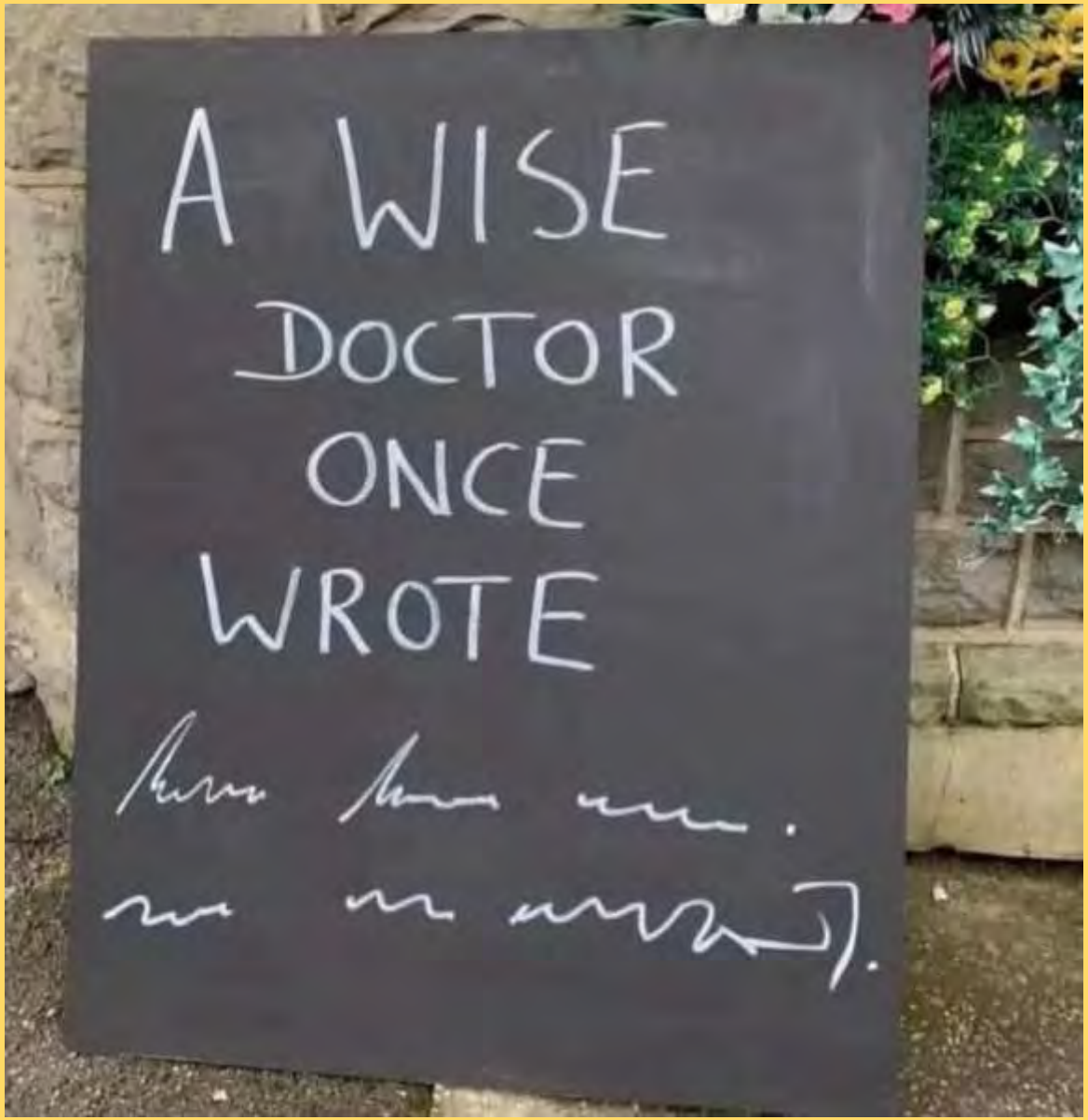
"Shortener dominant vs.Lengthener dominant"

TA fully engaged,
CT completely disengaged

Pulse/Fry

"Chest" Low, full bodied	"Mixed"	"Head" HIgher, thinner

Implications Weakness with Vocal Disuse Post Vocal Surgery



Start With Preoperative Care?

May have bigger implications w/vocalists & others who have **“up-regulated” systems (professional voice users)** & **w/advanced age.** Voice rest spanning >2 weeks may delay recovery to presurgical state. (Sandage, M., ASHA article)

- Disuse concerns w/voice in presurgical voice protocols.

Postoperative Care/Acute Inflammation

Wound healing time (Verdolini Abbott, K, Li, Nicole, 2012)

- Voice rest spanning 2-4 days often prescribed & would have little down regulating, BUT…
- Voice rest >2 weeks detrimental to neurometabolic & muscle fiber alterations, lengthening return to baseline status & even bigger implications w/ aging pt's.

Possible ex's post surgery for power, strength, stamina & neural adaptations, while protecting the VF's from mechanical trauma:

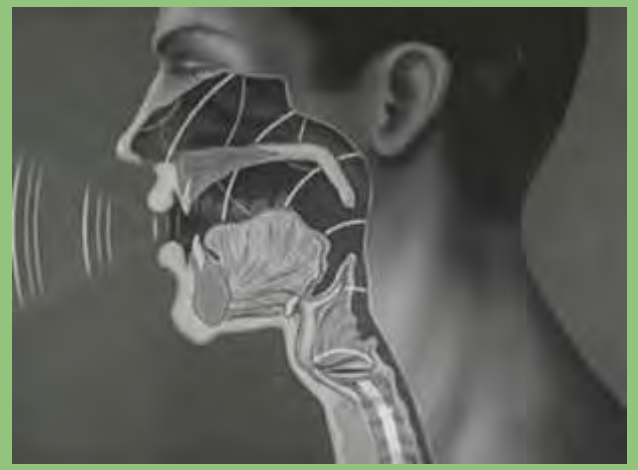
- VFE's
- SOVT with individualized vocal tasks for specificity
- Messa di voce (>< volume at =pitch)

Evidence Supporting **Modified Voice Rest**
Prior To Surgery

Acute laryngeal inflammation:RVT reduced laryngeal inflammatory markers better than spontaneous speech or prescribed vocal rest. (Verdolini, Abbott et al., 2012)

Sandage comments about expansion of this idea to vocalists & professional voice users to avoid losing too much match fitness.

RLN Paresis/Paralysis



Evidence of improvements w/strengthening in **early unilateral VF paralysis:**

- 12 week protocol
- VFE's, hard attack, & RVT
- Improvements: glottal closure; voice quality; acoustic measures & Functional Subscale of the VHI. (Fugimaki, TSunoda)

Superior Laryngeal Nerve Paresis/Paralysis

- Injury to external branch to the CT in thyroidectomies: reported to be as high as **58%**. Laryngoscopy-subtle signs. Compensation of the thyroarytenoid can mask it (Roy et al.).

- Reduced airflow w/normal voicing, increased subglottic pressures, reduced phonatory stability, increased jitter.

- Loss in **not just high but also low F0** & also impacts versatility of **shift between voiced and voiceless** phonemes. So think about this w/ exercise protocol development

Inhalation Phonation:

- MTD, granuloma, benign VF lesions, VF scar, unilateral vocal fold paralysis, SLN paresis, spasmodic dysphonia, & functional dysphonia.
- Standard protocol use during videostroboscopy
- The research on inhalation phonation is focused on the speaking voice, but benefits apply to overall phonation. Used in singers with MTD successfully (Emerich & Reed, 2019)

What happens physiologically?...

- Diaphragm contracts
- Larynx descends (tracheal pull)
- Tongue/jaw relax & velum lifts
- Ventricular fold separation
- Opposite mucosal wave (reverse Bernoulli effect)
- **CT activation occurs w/ VF lengthening**
- Decreased arytenoid compression
- Lengthening & widening of hypopharynx
- Instant elimination of A-P constriction
- VF adduction, but not through the full membranous cord
- Overall contact instability resulting in increased airflow
- F0 increases
- Mucosal wave increases & normalizes amplitude of waveform
- Steeper slope of harmonic peaks in the acoustic signal

Take Aways: Targeted conditioning programs **manage & plan for fatigue**.

- Know the functional end goal
- Voice users w/normal systems already using voice day-to-day most likely do not benefit from standard vocal strength programs as it is homeostatic use, and at “match fitness”, however in **disorders** (stroke. disuse atrophy, & muscle tension dysphonia, aging etc.) there is likely benefit.
- Likewise, vocalists/professional voice users benefit from a **mixed athletic program for endurance and ballistic activity**.

(Take-aways cont'd)

- **Call Centers, full time classroom teachers:** an anaerobic/aerobic athletic profile mix should be considered with bursts and stamina elements.

- **Warm-up** 10-20 min for singers is very important

- Accessory abduction/adduction function of the CT with inhalation phonation may offer a strengthening opportunity in SLN paresis w/o promoting MTD w/ very short bursts of **inhalation-exhalation phonation**.

- PCA as the only laryngeal muscle with higher endurance based fibers, can be trained with **IMST** (Sandnes, Andersen et al)

(Take-aways' cont'd)

- It takes a lot of exertion to fatigue respiratory muscles. More than used w/ voice production. So **really look at who actually needs RMST**

- Strong vocal strengthening programs account for the non-linear nature of voice production (articulatory, vocal tract, VF's & respiratory system) so demands good assessment for ACTUAL weakness in subsystems

- Avoid "downregulating" **singers and elderly too much before surgery,** use RVT and SOVT as modified voice rest.

- Caution with extrapolating limb exercise physiology science to laryngeal muscles. More research is needed.

Now let’s get lunch!

References:

Arbitol, J., The Odyssey of the Voice, (2005)

Baker, Susan E, (2003) Expiratory Muscle Strength Training And Detraining: Effects On Speech And Cough ProductionUniversity of Florida

Banks, R, Bottalico, P. and Hunter, E. (2017) The Effect of Classroom Capacity on Vocal Fatigue as Quantified by The Vocal Fatigue Index, Folia Phoniatr Logop 2017;69:85-93

Black & Hyatt 1969, *Maximal respiratory pressures: Normal values and relationship to age and sex.* American Review of Respiratory Disease, 99, 696-702.

Bausek, N. JSLHR Letter to the Editor Regarding Instrumental Assessment of Aeroresistive Expiratoey Muscle Strength Rehabilitation Devices" October 8, 2024

Dewan, K., MD, Vahabzadeh-Hagh, MD et al. (2017) Neuromuscular Compensation Mechanisms in Vocal Fold Paralysis and Paresis, Laryngoscope; 2017; July; 127 (7): 1633-1638.

Emerich Gordon, K and Reed, Ona, The Use of Inhalation Phonation in the Voice Studio: A New Approach to Addressing MTD in Singers, Journal of Singing, January/February 2019

https://www.nats.org/_Library/JOS_On_Point/JOS-075-3-2019-271_-_The_Use_of_Inhalation_Phonation_-

Emerich Gordon, K and Reed, Ona, The Use of Inhalation Phonation in the Voice Studio: A New Approach to Addressing MTD in Singers, Journal of Singing, January/February 2019

https://www.nats.org/_Library/JOS_On_Point/JOS-075-3-2019-271_-_The_Use_of_Inhalation_Phonation_-_Gordon_-_Reed.pdf

Fujimaki, Y., Tsunoda, K., Independent exercise for glottal incompetence to improve vocal problems and prevent aspiration pneumonia in the elderly: a randomized controlled trial Clin Rehabil. 2017 Aug; 31(8): 1049–1056.Published online 2016 Oct 14. doi: 10.1177/0269215516673208
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5524188/

Gill, B , Lee, J., et al. Spectrum Effects of a Velopharyngeal Opening in Singing
https://doi.org/10.1016/j.jvoice.2018.11.014

Johnson, A.M. and Sandage, Mary J. *Exercise Science and the Vocalist* New York, New York and Auburn Alabama 2019

Kao, Y, Chen. S., et al., **E**fficacy of Voice Therapy for Patients With Early Unilateral Adductor Vocal Fold Paralysis 2017 Sep;31(5):567-575. doi: 10.1016/j.jvoice.2017.01.007. Epub 2017 Apr 7.

Orestes, M. & Cchetri, D., Superior Laryngeal Nerve Injury: Effects, Clinical Findings, Prognosis & Management Options. Current Opin Otolaryngology Head Neck Surg. 2014 Dec;22(6):439-443

Robinson, Dan K. Dr. Dan Youtube

Roy et al. *Annals of Otology. Rhinology & Laryngology* I2O(I) : I - 8.2011 Annals Publishing Company.

Sataloff, R T, Treatment of Voice Disorders, 2005. doi:1002/lary.26409.

Sandnes, Astrid , Andersen, Tiina et al (2019) *Exercise-induced laryngeal obstruction in athletes treated with inspiratory muscle training,* BMJ Open Sport & Exercise Medicine

Sandage, Mary J. *Perioperative Voice Recovery: An Exercise Physiology Perspective*, accessed 02/27/2024 https://pubs.asha.org/pubs/rights and permissions

Saunders, William, Reprinted from *Clinical Symposia*, *Volume 16, Number 3* 1964

Smith, Audrey G., Sandange, M. et el. Elementary school teachers' vocal dose: Muscle bioenergetics and training implications

Verdolini Abbott, K., Li, Nicole A.K., et al. Vocal exercise may attenuate acute vocal fold inflammation, J Voice. 2012 Nov;26(6):814.e1-814.e.13.

Verdolini, K, Titze, I and fennell, A. Dependence on Phonatory Effort on Hydration Level JSLHR, 1 Oct. 1997

Links/Resources:

Vocal Strengthening ASHA Evidence Maps: https://apps.asha.org/EvidenceMaps/Maps/LandingPage/7b7ce62d-420c-4463-bf37-7f1cb9c3d461, 2024

Role of the Muscles of the Larynx: Mentathlete YouTube Video https://youtu.be/dvQPjHVENrg?si=146bgqPL203CEnfT

https://apps.asha.org/EvidenceMaps/Maps/LandingPage/7b7ce62d-420c-4463-bf37-7f1cb9c3d461