EOS Treatment Outcomes
Are We "Helping?"
What Do We Know ?

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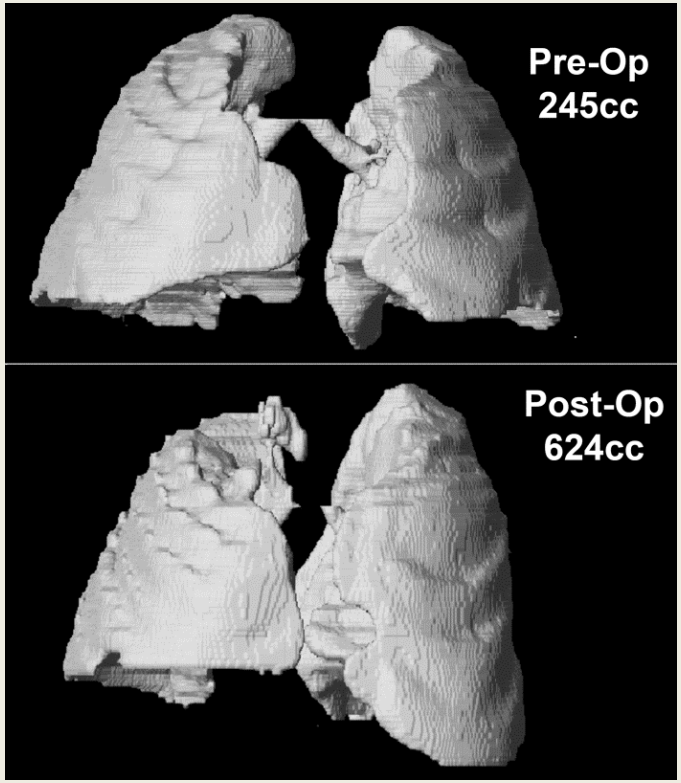
EOS Treatment Goals

- Control/correct deformity while permitting…..
- Elongation of spine
- Increase thoracic volume

⟶ Satisfactory pulmonary function @ maturity

- QOL improvement occurs simultaneously ?



Size matters ?

The basics - Fusion prior age 4-5

- Goldberg ('03) – "….early surgery, even with anterior growth arrest…did not halt the deformation of scoliosis and did not reliably preserve respiratory function in this group whose scoliosis presented before age 4."

- Emans ('04)
- Karol ('08)
- Vitale ('08)
- Typical PFT's 20-50% pred. when tested 10 yr later

Well established that thoracic fusion < age 5-8 is associated with TIS

Goldberg et al *Spine 2003*

11 patients < 8 yr (1.4-7.8)

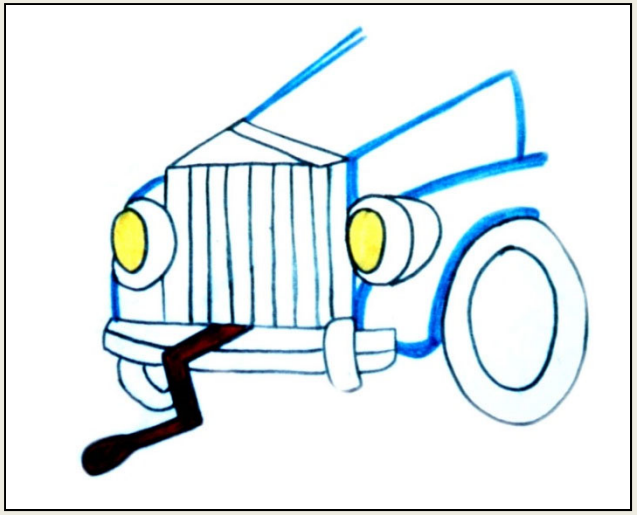
PFT's @ 20.5 yr. (15-30)

FEV1 = 41% (14-72)

FVC = 41% (12-67)

If fusion delayed to age 10

⟶ PFT's = 70% mean (45-100%)

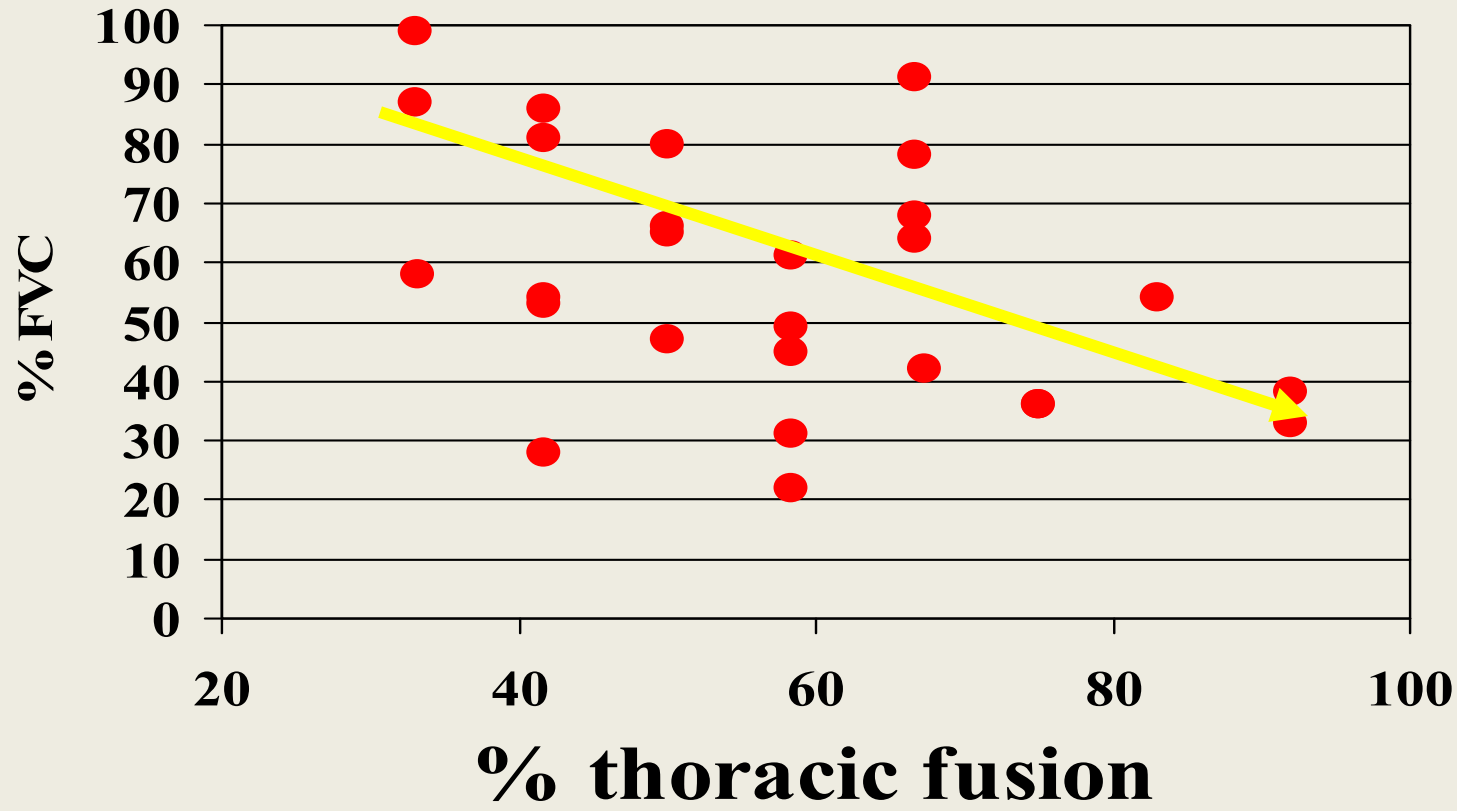


TSRHC study (Karol et al, JBJS 6/08)

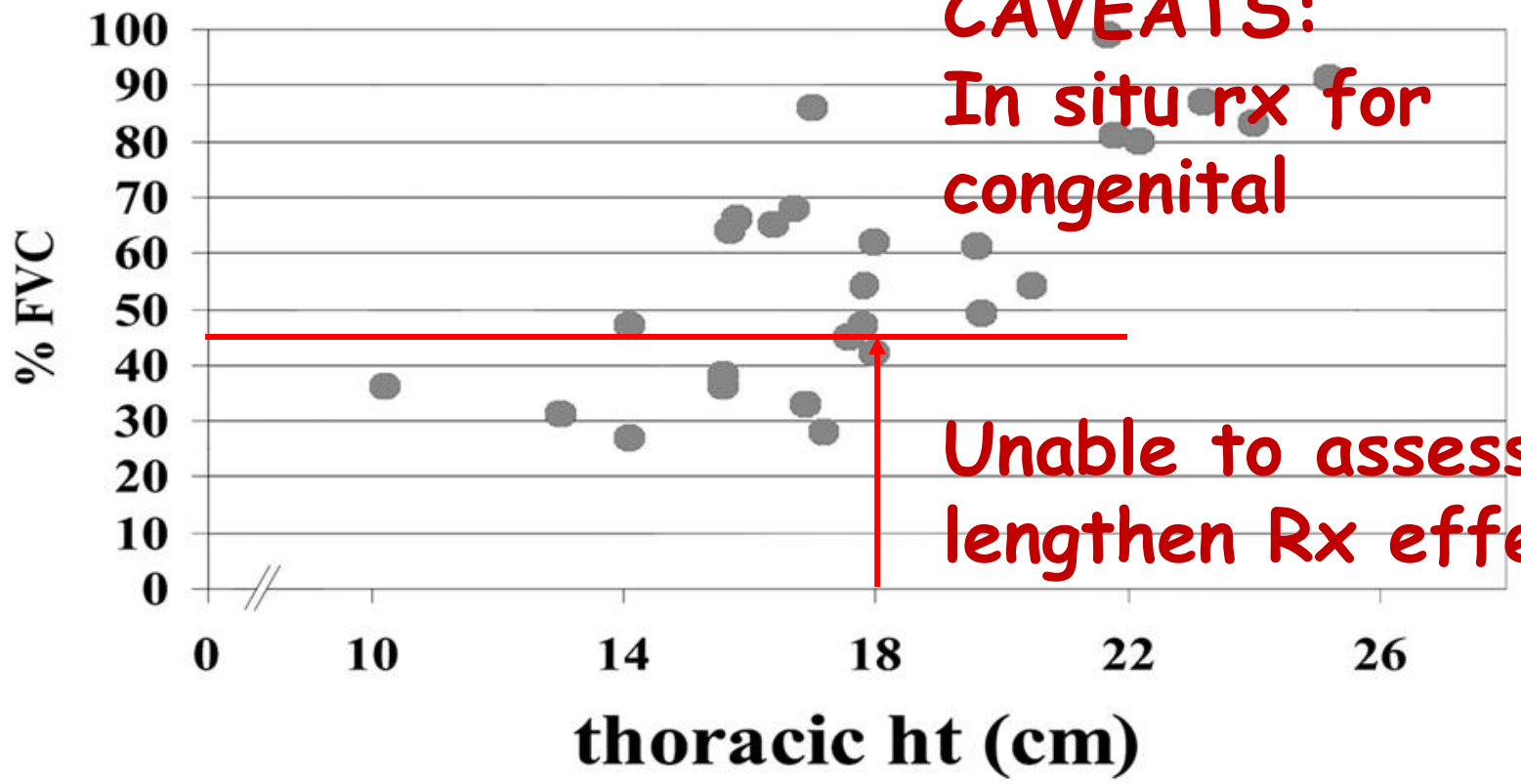
Fusion age 3.3 yr, f/u 11 yr

FVC 58% (27-99)

FEV1 55% (23-91)



Goal of RX: T1-12 length > 18 cm



CAVEATS:
In situ rx for congenital

Unable to assess lengthen Rx effect

Karol L. A. et.al. J Bone Joint Surg 2008:90:1272-1281

Objective Measures - Criteria to Justify Intervention

The Latest

- Conventional Cobb measures
- Thoracic parameters / pelvic width
  - Length (affected directly by correction)
  - Width (correlation to CT volume)
  - Sagittal depth (?)
- CT volume (esp. serial studies)
- Respiratory parameters (RR, O_2 sat, bipap)
- PFT's > age 6 (too late to use as pre-op indication)
- BMI / weight gain
- Dynamic MRI – coming soon [role of expansion diaphragm-plasty]

What we don't know……

- Correlation between thoracic parameters (Th spine length, rib length) and PFT unavailable

  [no correlation between Cobb improvement and PFT w/ CW devices] Mayer/Redding
- No PFT data for GR patients' outcomes
- Does thoracic expansion actually reverse alveolar hypoplasia ? Snyder et al
- Effect of CW devices on circumferential thoracic volume after age 10 Dimeglio
- Severity index / classification @ onset

GR Graduates – PFT Outcome

SRS 2015 eposter #42

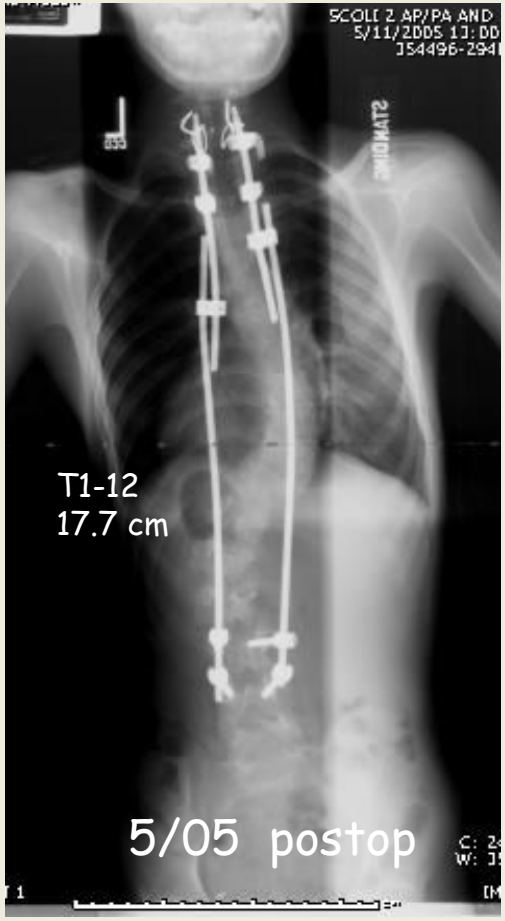
- 8 patients : 3 - IIS, 1 – idiopathic-like, 1 - congenital, 1 - n-m, 2 – syndrome
- Main curve 90° (60-123)
- Age (preop) 73 mo (48-97)

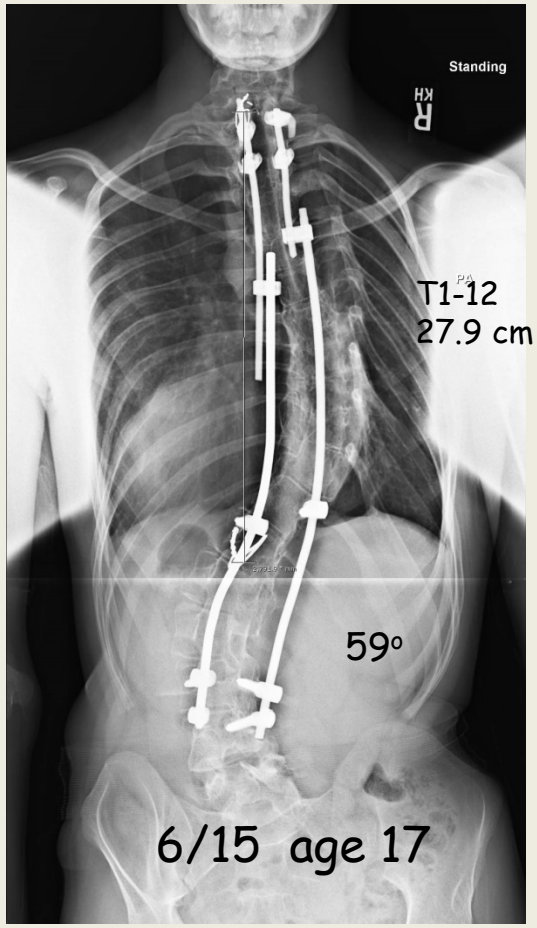
  incl. preop non-op delay 44 mo (19-62) in 4 pt
- Most recent surgery @ 129 mo (121-157)

  4: definitive fusion, f/u 1-2.4 yr

  4: lengthening only, f/u 3-4 yr observation

- Total procedures (mean) = 8.3
  1 initial implant, 1 unplanned revision/I&D,
  6.2 planned lengthenings (3-9)
- 7 rod/anchor complications / 4 patients





Results Xray

	Age (mo)	T1-12 (cm)	Curve °
Preop	73 (48-97)	13.9 (9.9-17.7)	90 (60-123)
Last surgery	129 (121-157)	22.8 (18.6-29.5)	39
Last f/u	168 (133-204)	**23.9** (20.3-29.6)	46 (26-53)

Results – PFT's

	FEV_1 (L)	FEV_1 % pred	FVC (L)	FVC % pred
PFT #1 6+9 yr (4+10-8+7)	.69 (.37-1.2)	58 (26-96)	.75 (.48-1.2)	59 (30-115)
PFT f/u 14 yr (11+6-17)	1.7 (1.07-2.44)	**51.8** (36-62)	2.1 (1.34-2.99)	**57.5** (39-76)

Summary / 8 yrs treatment

- T1-12 length gain cm 13.9 -> 23.9**
- Curve magnitude 90 -> 46°
- Complications n=7 (4 pt.)

**** 18 cm T1-12 length @ maturity = threshold to avoid risk of restrictive lung disease** (Karol '08)

Normal T1-12 length age 10 = 22 cm (Dimeglio '01**)**
(age where definitive fusion usually acceptable)

Conclusion - Outcome

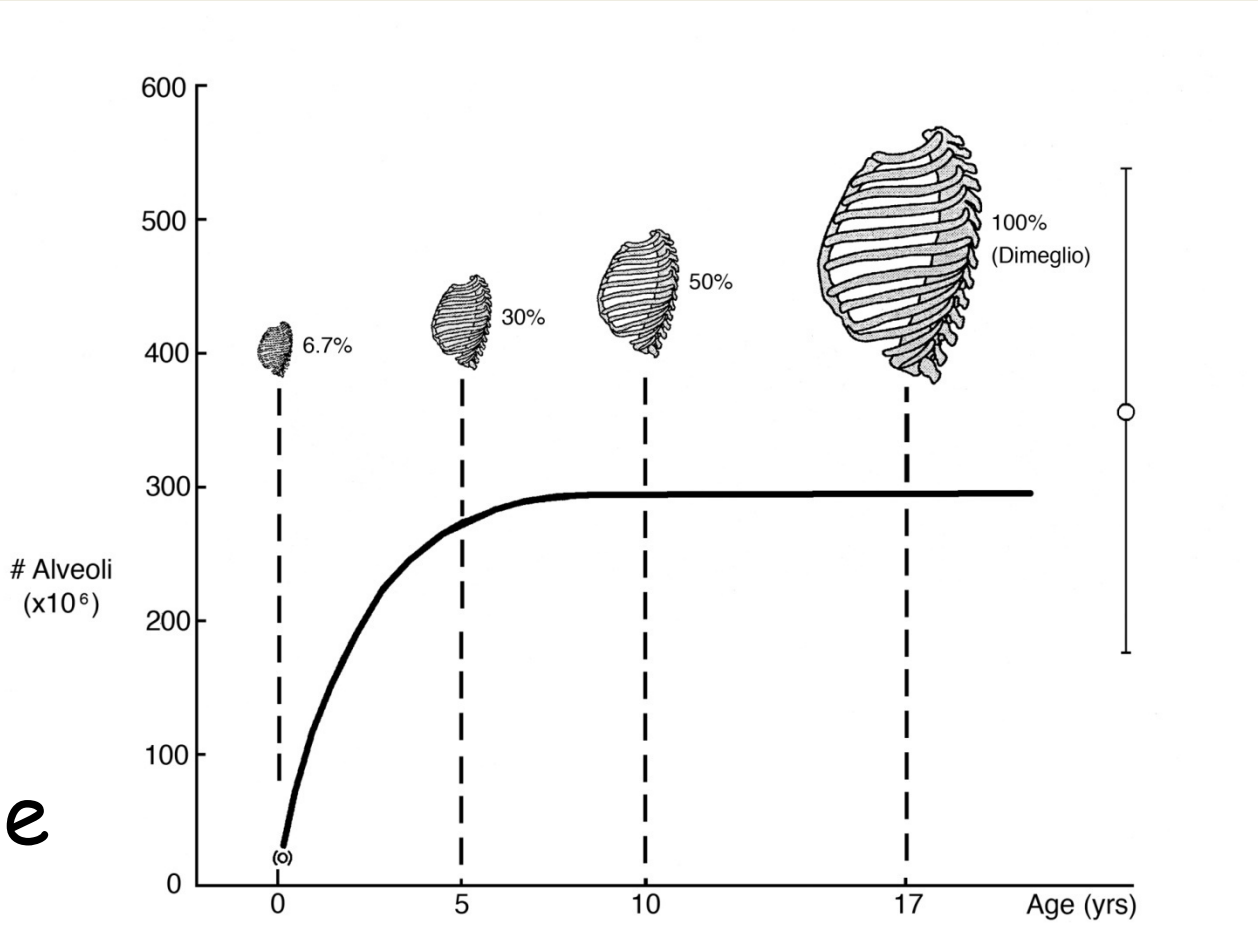
In spite of what appears to be satisfactory thoracic length gain and curve correction over 8 years of treatment, with acceptable complication rate, pulmonary outcomes (as measured by % predicted volume) are modest at best

Pulmonary volume increase not keeping up with expected volume increase due to growth

Hyperplasia

&

Hypertrophy



Thoracic Volume

Birth	6.7%	of final volume
age 5	30%	"
age 10	50%	"

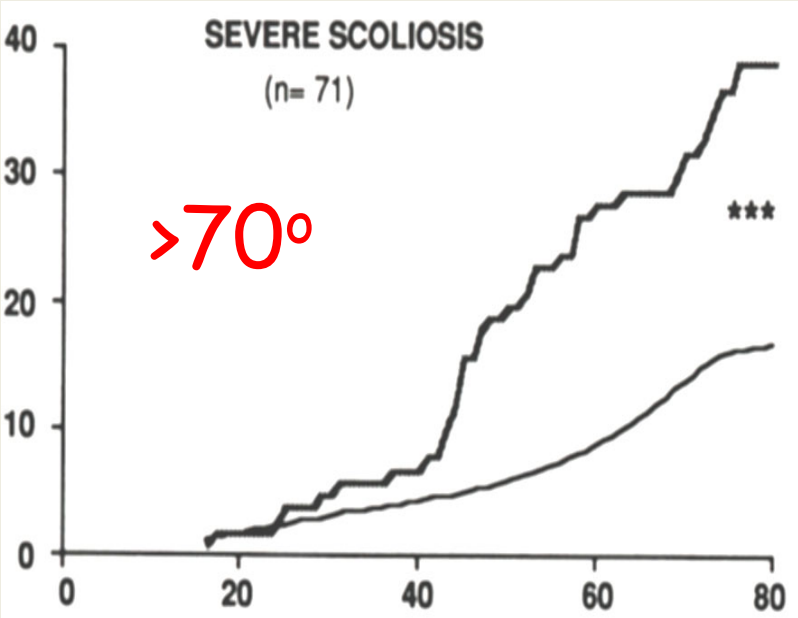
What we know….

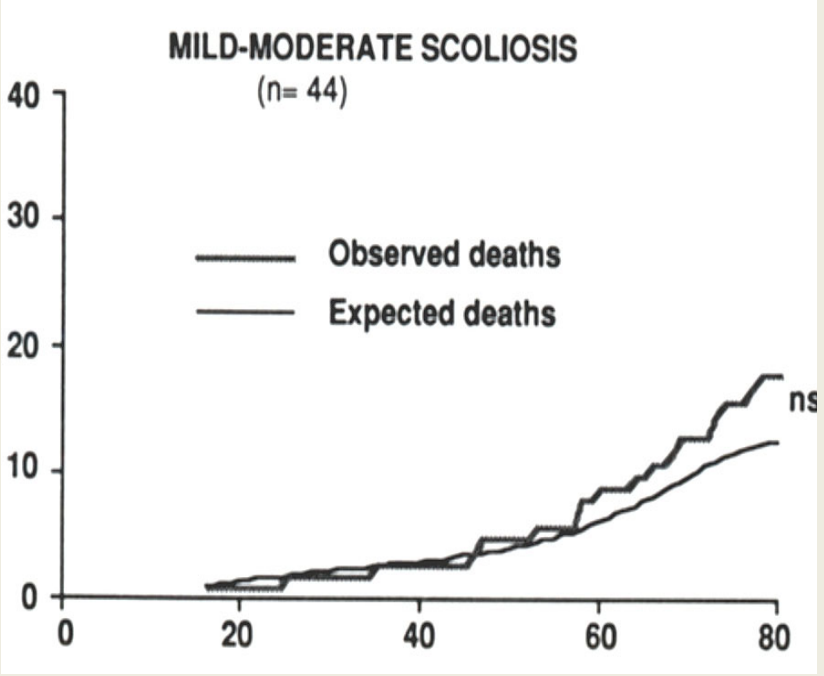
- Natural hx large curves

↓

Increased mortality
(Pehrsson)

PFT's < 45% pred.
@ maturity





OTHER FUNCTIONAL TESTING ?

- **Growing rod treatment designed to delay spinal fusion so the thorax can continue to grow, potentially increasing lung volume**

- **Poor PFT values have been reported in EOS grads who have undergone growing rod treatment**

  ~ 50% pred FVC % and FEV_1% (SRS 2015 eposter)

- **Clinical impression: kids with EOS are limited, not as active as their peers**

Step Activity Monitoring to Assess Functional Outcomes in EOS "Graduates"

- **11** patients (3 more !!) with EOS were invited to wear a Step Activity Monitor (SAM) (StepWatch™, Modus, WA)
  - Prospective IRB approved study
- Wear time a.m.- bedtime

RESULTS Demographics

	EOS n=11	Control n=20	p value
Age at test	12.6	13.1	0.592
Height	150	157	0.215
Weight	38.8	52.2	0.090

	EOS Surgical			EOS PFT			
	Last Sx months	Definitive Fusion	Observation	FVC_{abs}	FVC %	$FEV_{1\ abs}$	FEV_1 %
EOS n=11	**42.2** ***23.9-66.2***	6/11	4/11	**1.2 (0.48-2.04)**	**48.4 (23-80)**	**1.2 (0.40-2.59)**	**50.5 (15-77)**

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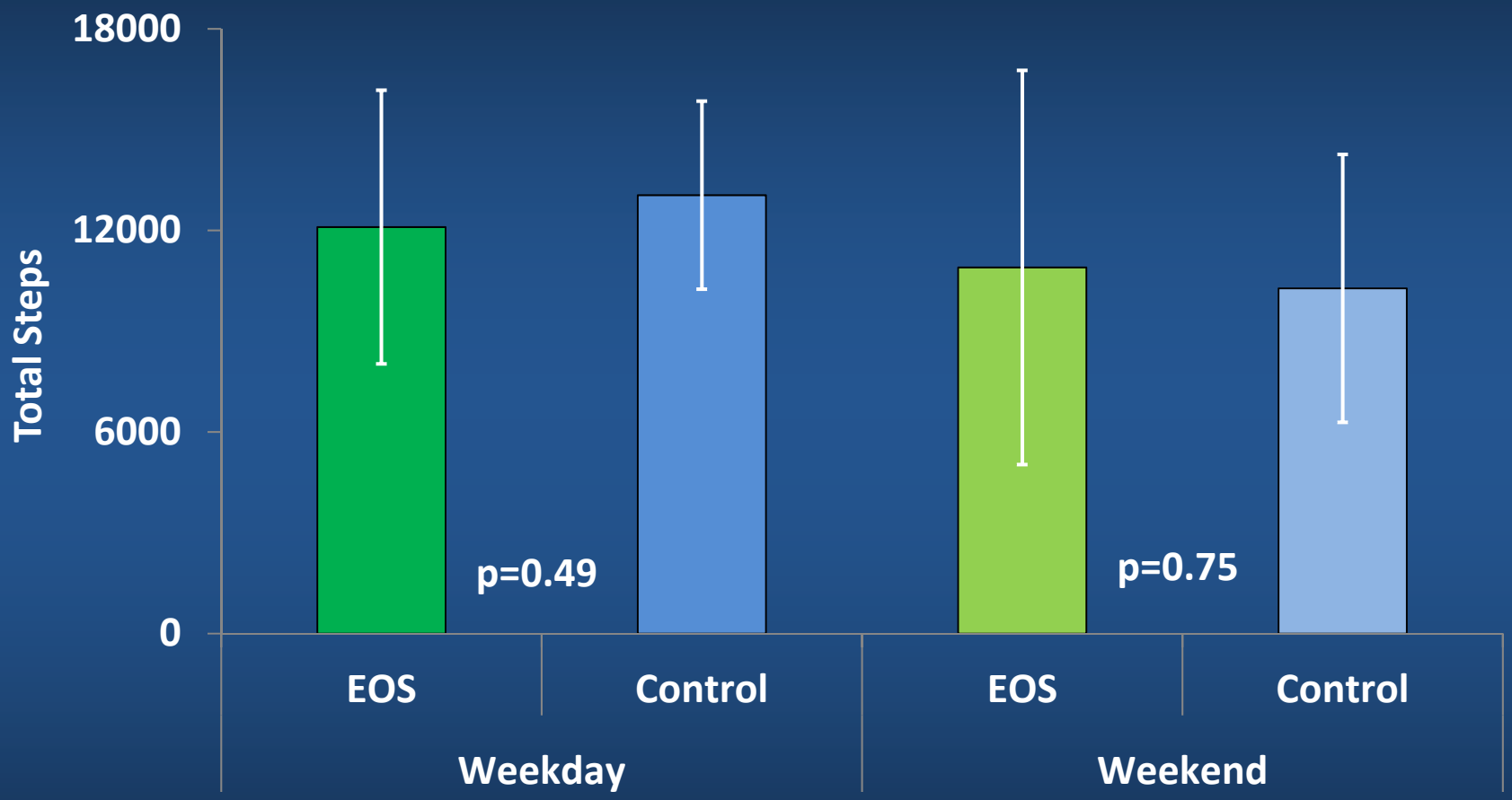
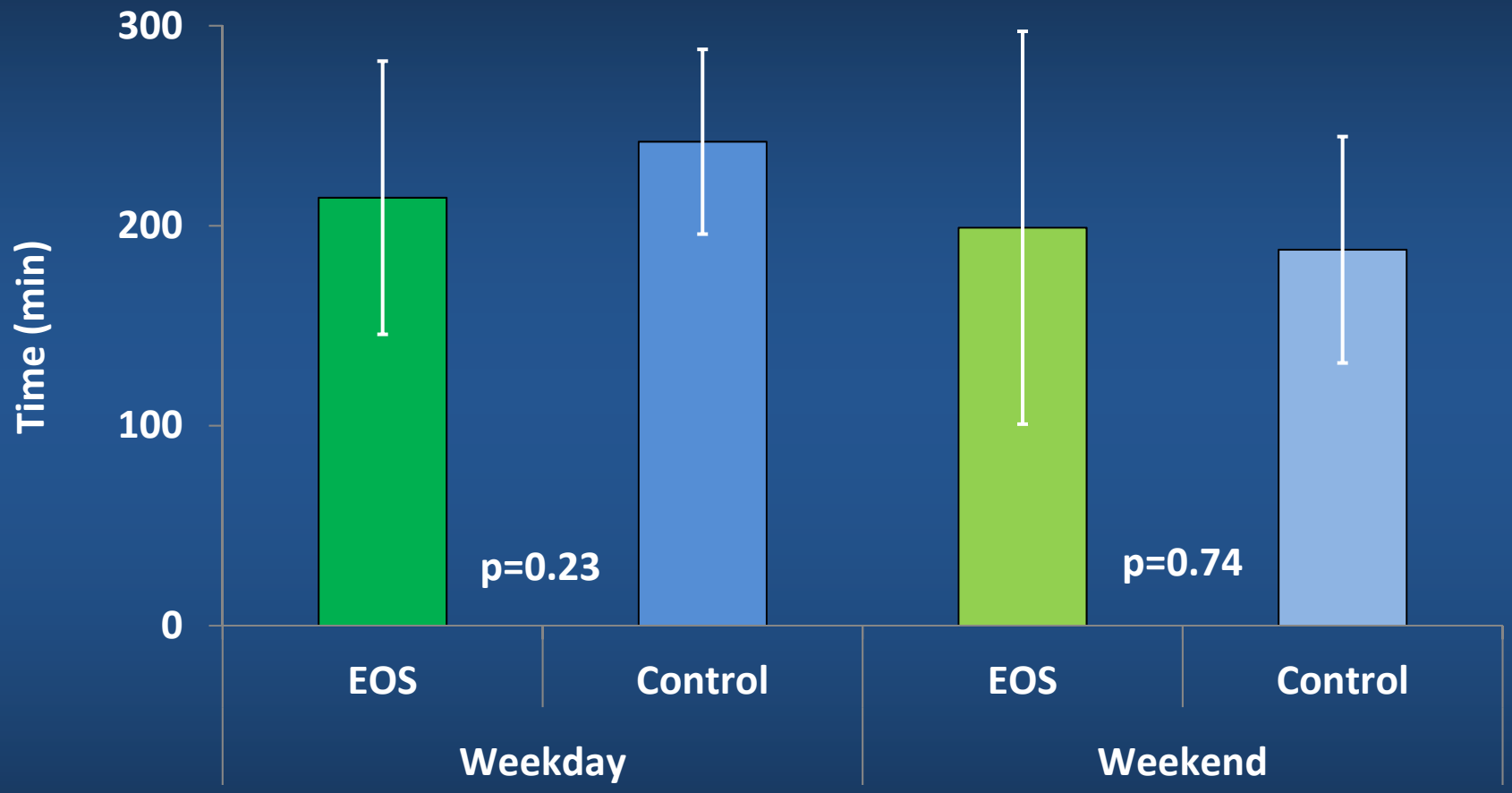
RESULTS Total Steps



- **Total Steps were the same for EOS and Controls**
  - Weekday and Weekend **P = ns**

RESULTS Total Active Time



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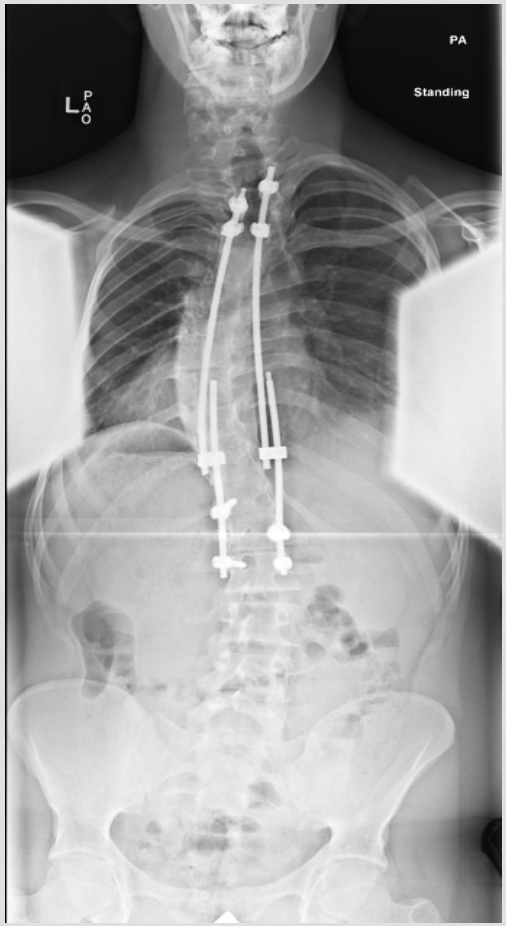
  - Weekday and Weekend **P = ns**

OUTCOME - CONCLUSION

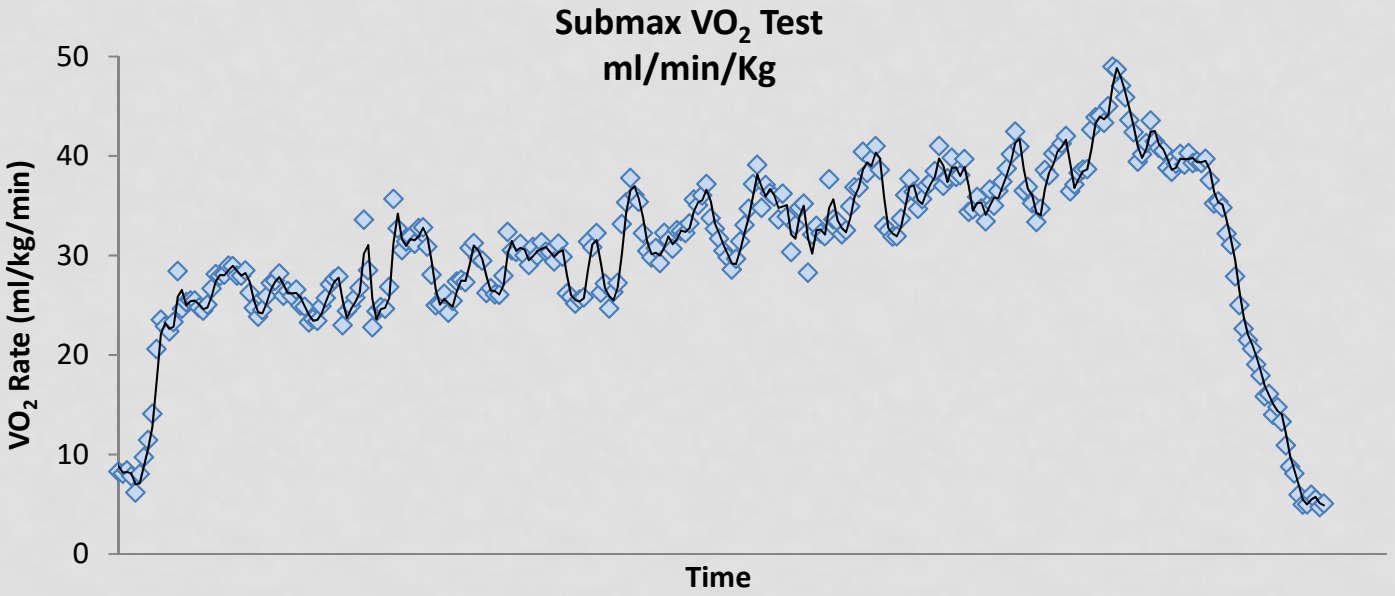
- PFT's – underwhelming result: ~50% pred value
  - No correlations were found to SAM data
- Step Activity data shows that patients with EOS take the same number of steps and spend the same amount of time in Activity during the week as their peers
- Despite pulmonary "limitations", daily activity measures suggest no significant limitation in activity or active time

Exercise Tolerance in Growing Rod "Graduates" – New Respiratory Functional Outcome Measure



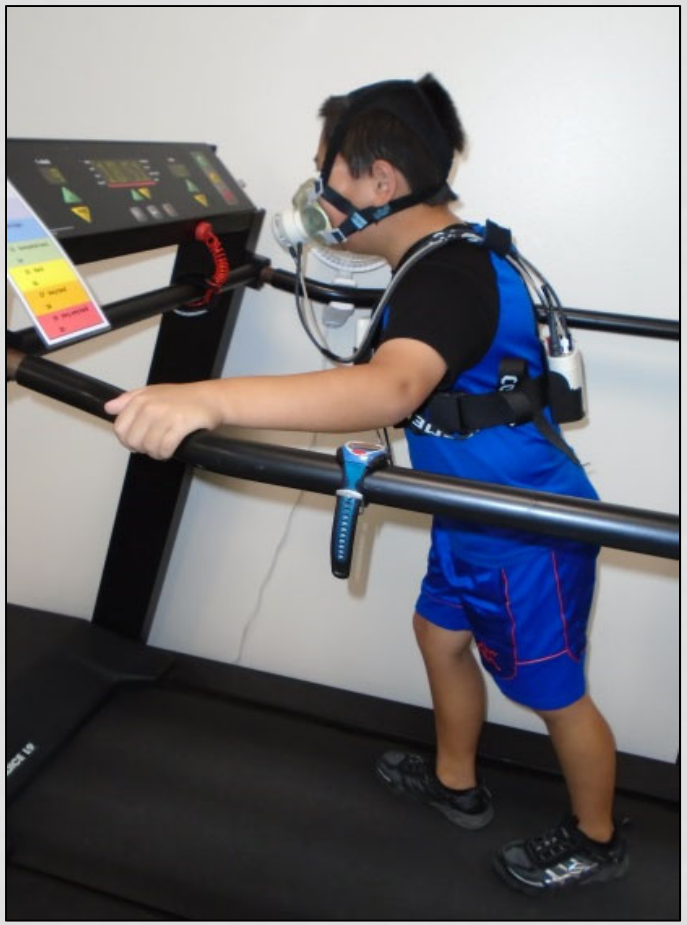
EXERCISE EVALUATION

- To evaluate exercise O_2 consumption during a graded exercise test
- Characterize respiratory capacity in EOS patients who are ≥1 year since last GR/definitive fusion surgery



METHODS: VO_2 CONSUMPTION TEST

- **VO_2 collected breath by breath by gas exchange portable system**
- **Heart Rate monitor**
- **Variables**
  - **Ventilation**:
    - Breaths/min (f)
    - Tidal volume (VT)
    - Ventilation (VE)
  - **Cardiovascular**:
    - HR, HR% - percent of age predicted HR max
  - **Metabolic** :
    - VO_2 Rate (ml/kg/min)
    - VO_2 Cost (ml/kg/m)
    - respiratory exchange ratio (R) VCO_2/VO_2
    - VO_2 max predicted
  - **Velocity** (mph)



PATIENTS: EOS VS. CONTROL

	EOS	Control	p value
N	**11**	**20**	--
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EOS	1.2 (.48-2.04)	48.4 (23-80)	1.2 (.40-2.59)	50.5 (15-77)

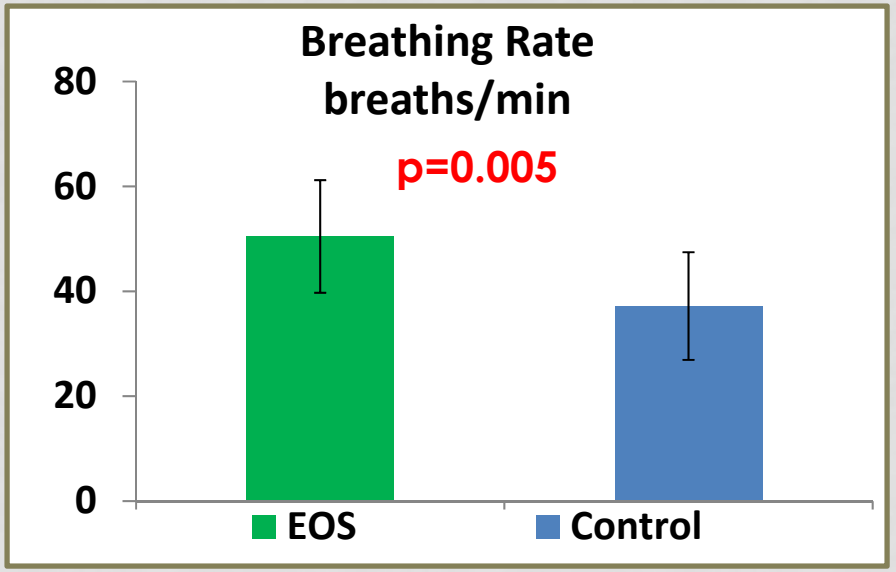
OVER-GROUND WALKING

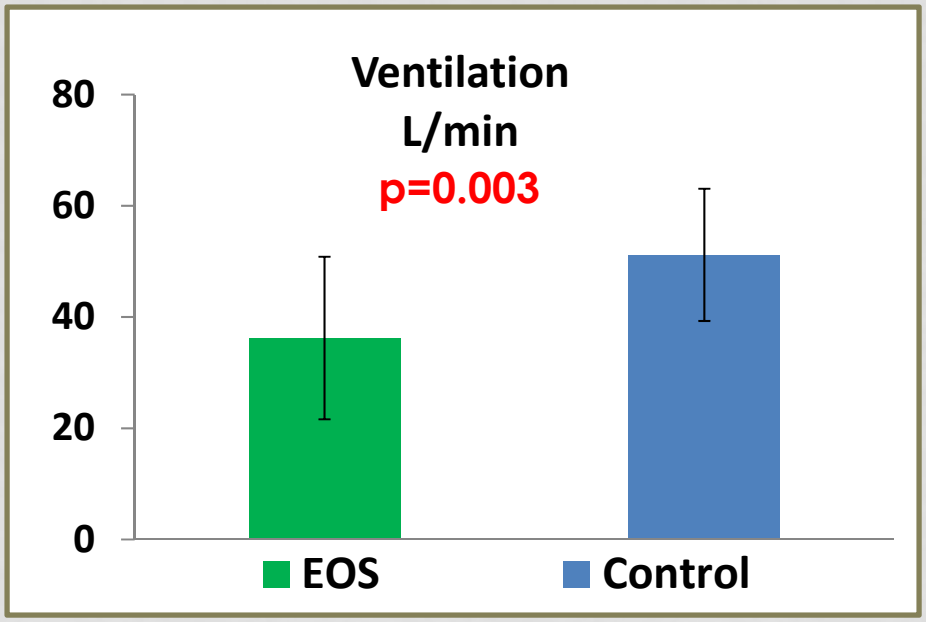
	VO_2 Rate ml/kg/min	HR bpm	VO_2 Cost ml/kg/m	Velocity mph
EOS	21.0	131	0.28	2.8
Control	17.5	117	0.22	3.0
p value	0.107	**0.021**	**<0.000**	0.083

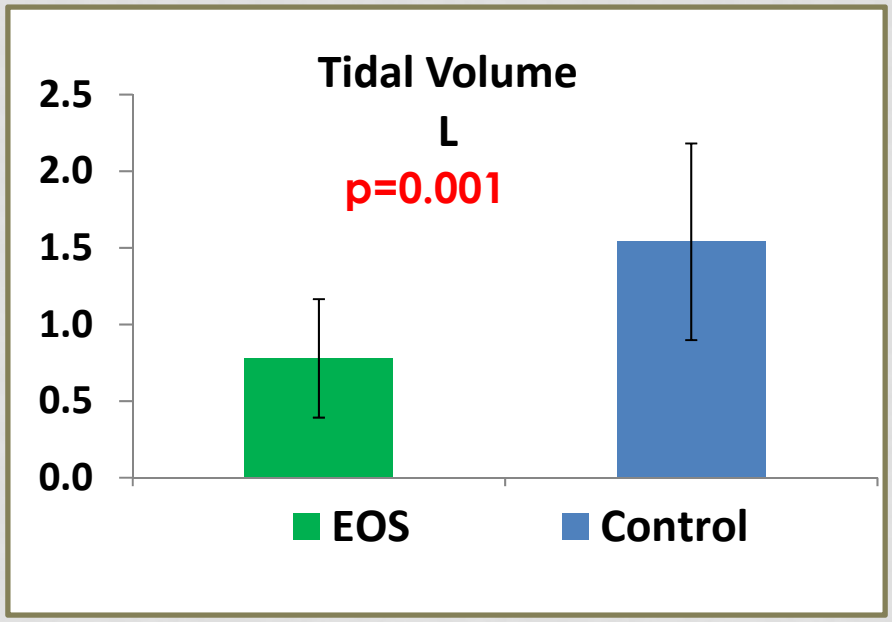
- At self-selected walking velocity
  - EOS group had a higher HR and increased VO_2 Cost
  - Velocity was not significantly different **p>ns**
    - ***Able to keep up with peers***

END OF TEST (eg 85% HR_{Max})

- Compared to controls, the EOS grads take:
  - 36% higher resp rate
  - Achieving 50% the Volume at
  - 70% Ventilation rate







END OF TEST (eg 85% HR_{Max})

	VO_2 Rate ml/kg/min	HR bpm	% HR max	Velocity mph	R* VCO_2/VO_2
EOS	28.2	164	79%	2.8	1.02
Control	34.2	174	84%	3.6	0.90
p value	**0.035**	0.231	0.433	**0.000**	**0.004**

- Heart rate is similar, but EOS group consumes less VO_2 while walking at a **slower** velocity
- EOS group is working harder than controls(R = 1.02)
  ***R ≥ 1.1 anerobic metabolism (nearly at VO_2 max)**

+VE CONCLUSION

- PFT suggests poor function ~50% pred
- VO_2 test demonstrates that GR graduates are able to keep up with their peers with typical everyday walking velocity
- They have the capacity to exercise but at a lower work load (slower speed) due to respiratory limitations

EOS Outcome – +ve ?

- PFT data uncertain, worrisome
  (test poor reliability)
- SAM, exercise tolerance tests encouraging -> keeping up
- QOL issues – tbd (Vitale, Redding, Yazici)

- Can similar/better outcomes be obtained with less rx sessions ?