Three Dimensional Kinematic Analysis of Regional Chest Wall Motion and Volume Changes During Respiration in Healthy Children

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Shriners Hospitals
for Children®
Portland, Oregon

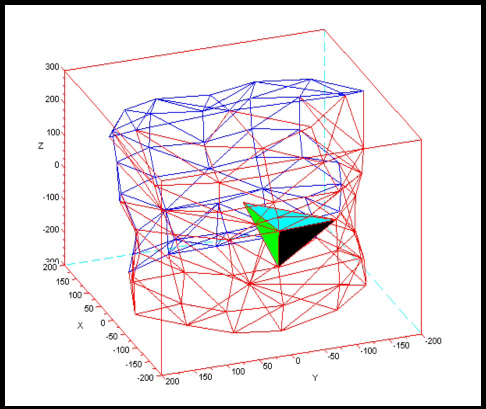
Motion Analysis Lab

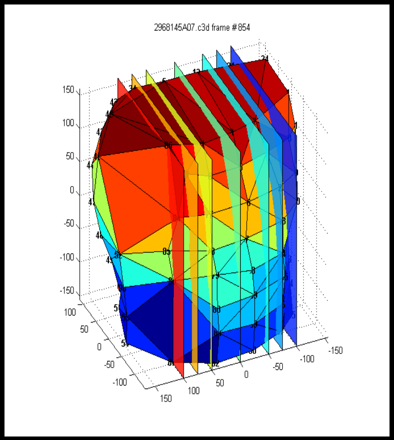
Optoelectronic Plethysmography (OEP)
Introduction

- Motion analysis laboratory (gait lab)
- OEP measures chest wall motion during breathing maneuvers
- OEP correlates well with conventional spirometry FVC and TV in adults

OEP Basics

- Markers on the chest
- Collect data during breathing maneuvers
- Define a triangle mesh with the markers
- Sum the volumes of the tetrahedra associated with each triangle
- Analyze in any plane

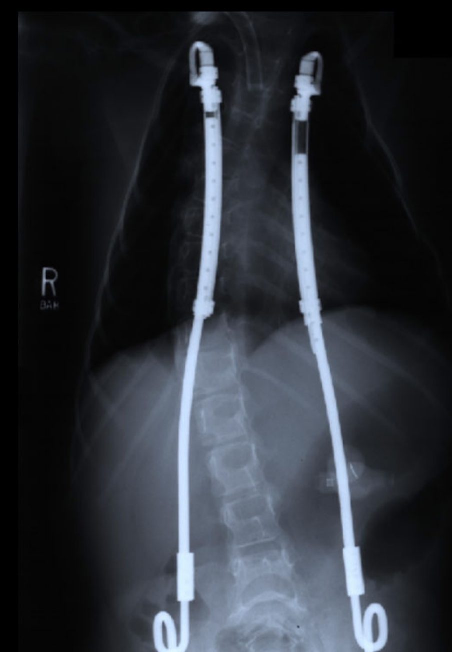




OEP

potential

- Study effect of interventions deformities or disease on chest wall motion
- “ PFT “in EOS treatment
- Non invasive, no radiation

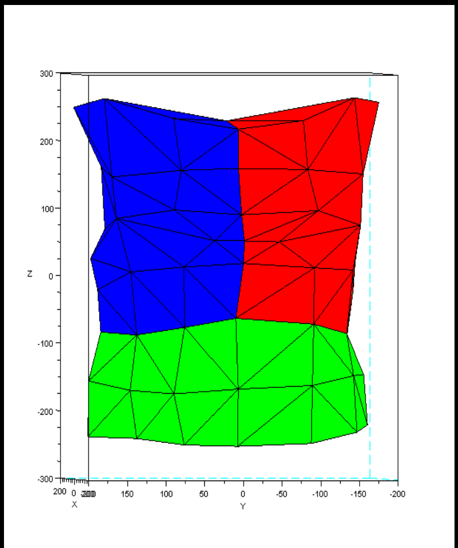


OEP Validated in Adults

- In normal subjects (Carnevali et al., 1996) speaking, breathing; exercising; flute
- With single-lung ventilation (De Groote et al., 2004)
- With hemiplegia (Lanini et al., 2003)

Regional analysis of motion

- Marker subsets show L, R and abd.
- Using ultrasound, the motion of the diaphragm may be inferred from the motion of the abdominal region (Wang et al., 2009)

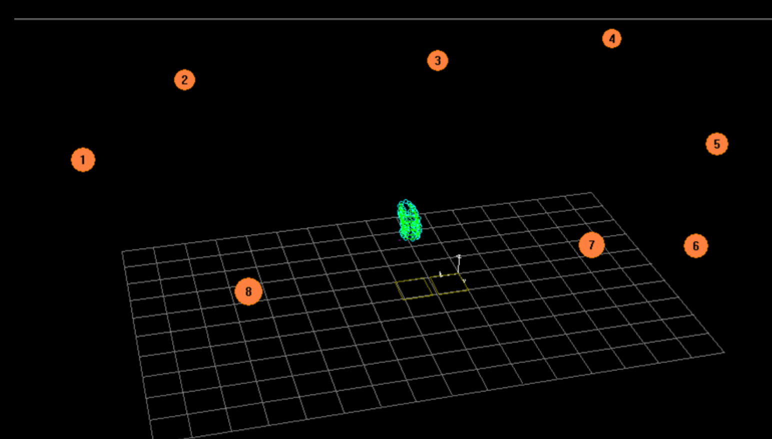


Purpose

- Compare OEP to pneumotachometer spirometry in normal children aged 8 – 12
- Establish ratios for regional thoracic motion and contribution to FVC
- Validate the accuracy of this method for future 3D chest wall motion studies

Materials and Methods

- 10 boys and 2 girls < 13 yrs
- No known respiratory disease, neuromuscular, skeletal problems, deformity, or chest wall trauma
- 10 Vicon infra-red cameras, 86 reflective markers (6mm), 42 front, 34 back, 10 lateral
- Each subject measured three times with simultaneous capture of OEP and Spirometry (Cosmed)®



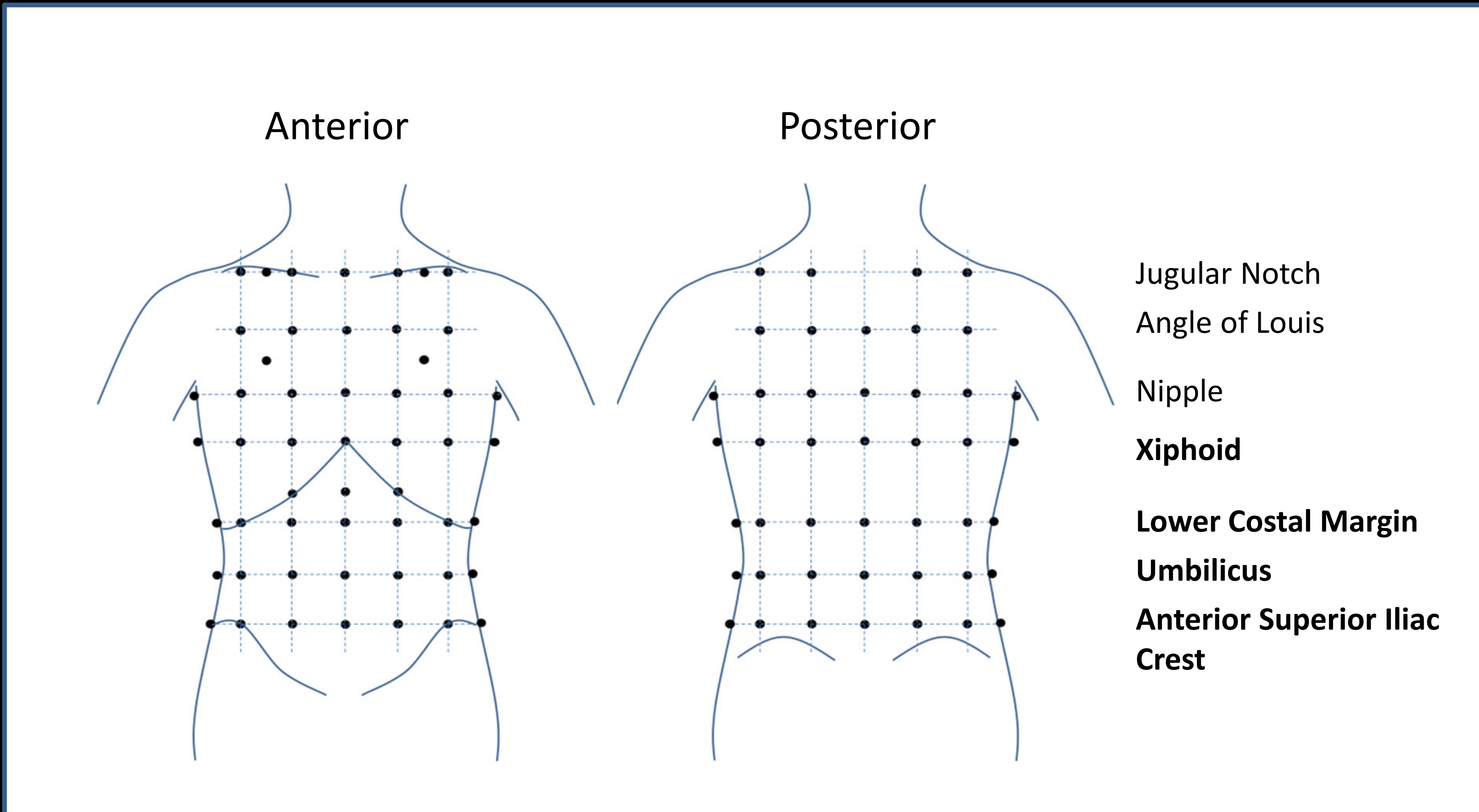


FIGURE 1. Markers on the body to define the chest wall as described by Ferrigno et al, 1994.

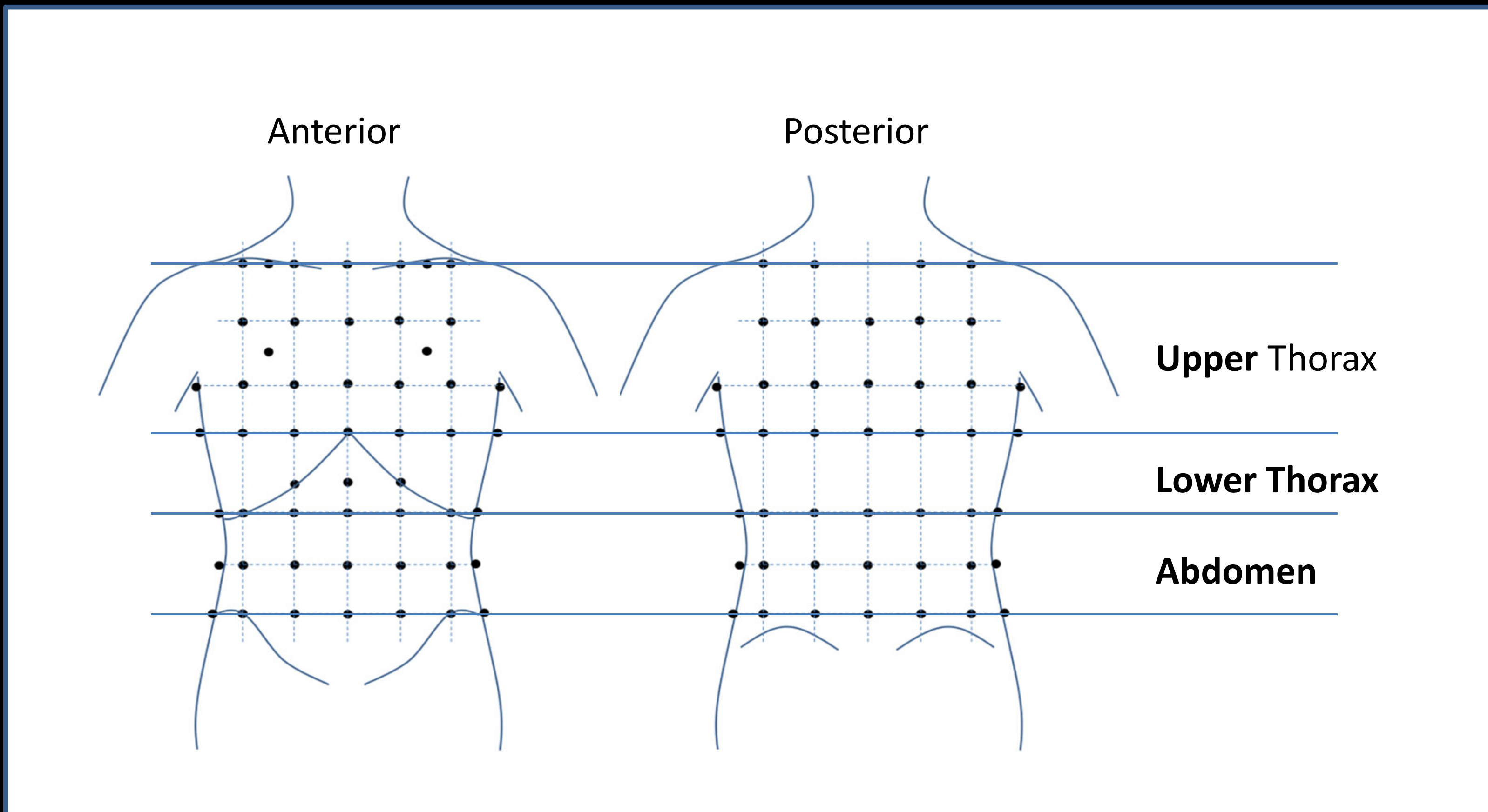


FIGURE 2. The chest wall separated into three compartments and left and right sides as described by Aliverti et al., 2002.

Results

- Mean age 9.90 ± 1.39 (8.08-12.2) years
- Mean FVC 2.07 ± 0.44 L by spirometry;
  Mean FVC 2.08 ± 0.42 L by OEP
  Pair T-test (*p* =.62)
- % error spirometry vs OEP was 2.19% ± 1.55 %
- Error close to five percent between different spirometry systems (Aliverti et al, 2000)

RESULTS

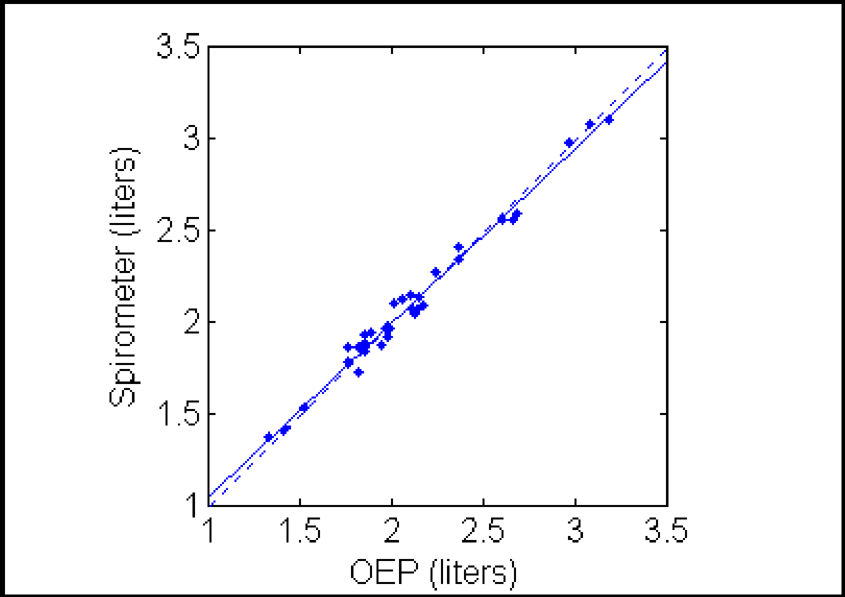


FIGURE 3. Scatterplot of FVC measured using spirometer and OEP.

FVC measures from the spirometer and OEP are strongly correlated.

- Linear regression slope of 0.9503 ($p<0.001$) and an intercept of 0.0987 ($p<0.05$)
- Pearson product-moment correlation coefficient = 0.9924 ($p<0.001$).

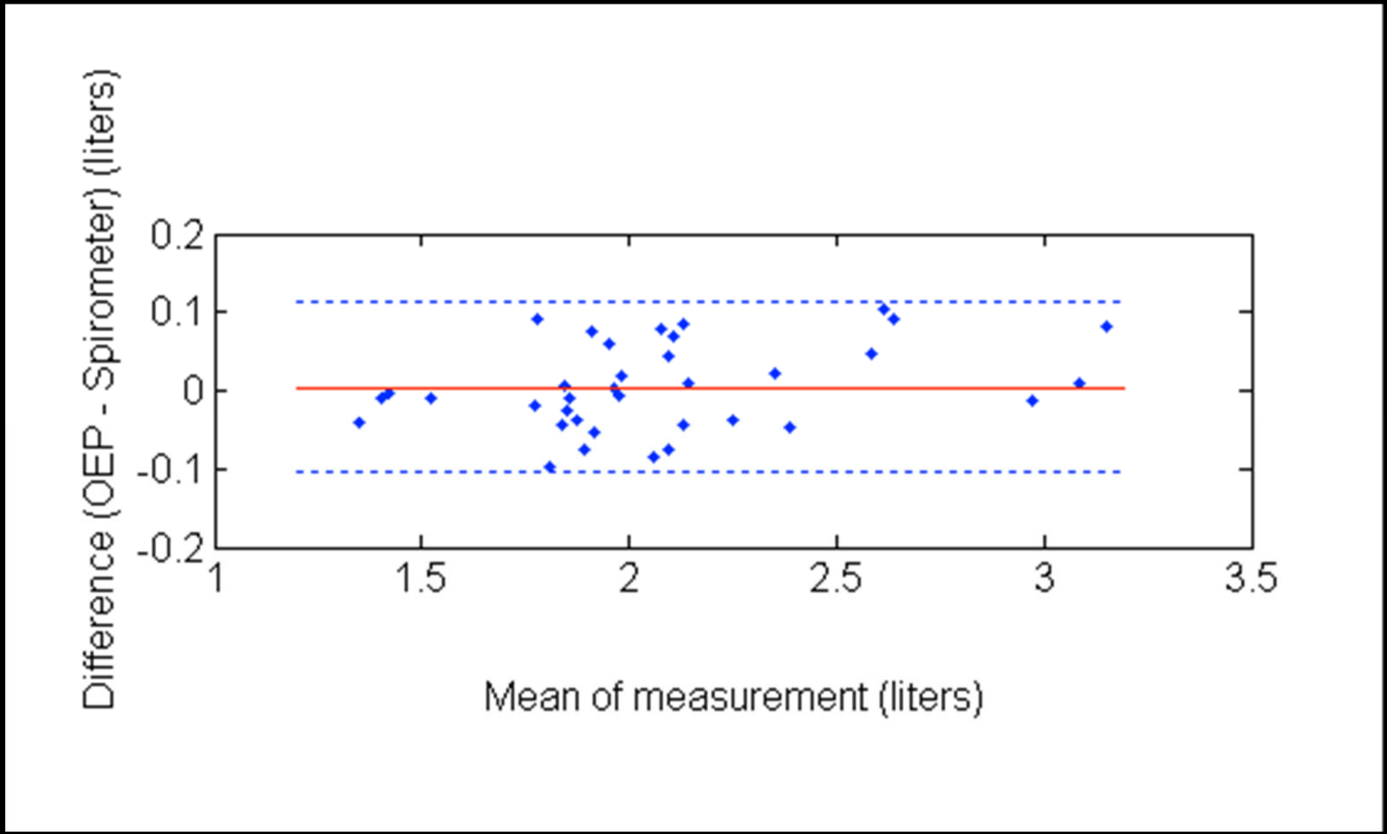


FIGURE 4. Bland-Altman analysis. The dotted lines are the ninety-five percent limits of agreement (mean ± 1.96 standard deviation), and the solid line is bias value (mean of difference).

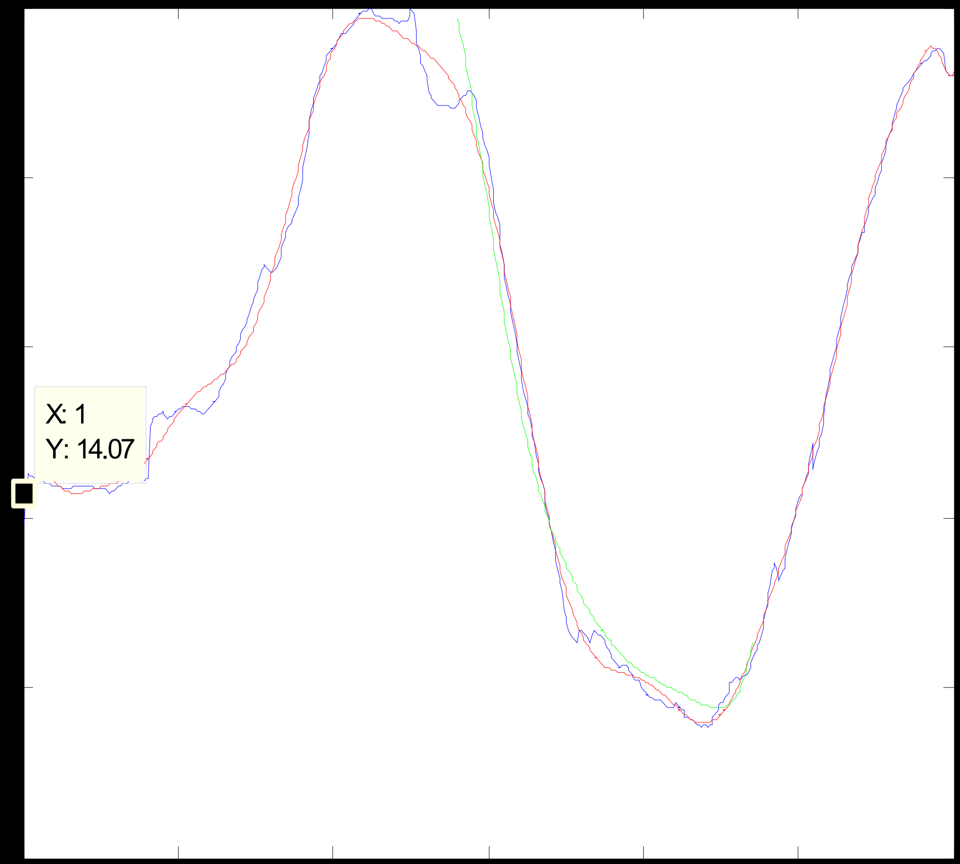
Bland–Altman plot showed good agreement between OEP and spirometry over the entire range of measurements.

Section	V_{UT}	V_{LT}	V_{AB}	V_{TOT}
FVC (L)	0.65 ± 0.14	0.41 ± 0.18	1.02 ± 0.26	2.08 ± .44
Contributions to total volume	31%	20%	49%	

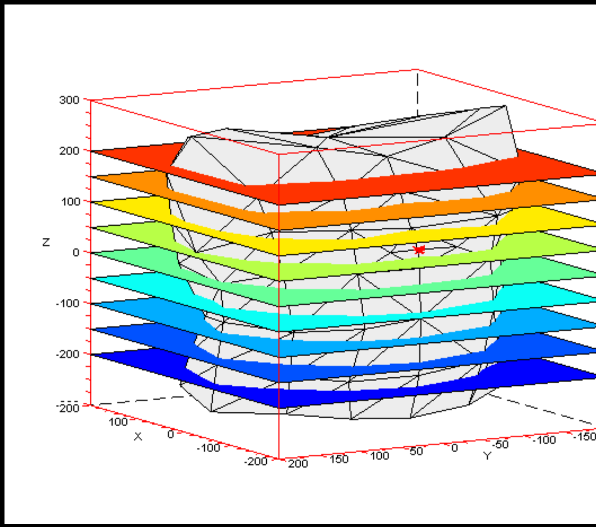
- Contribution to FVC differed significantly across the three compartments. F (2, 105) = 97.993, p <0.001. Post hoc analyses (Bonferroni): the average contributions to FVC are significantly different (p<0.001) between any two of the three compartments.

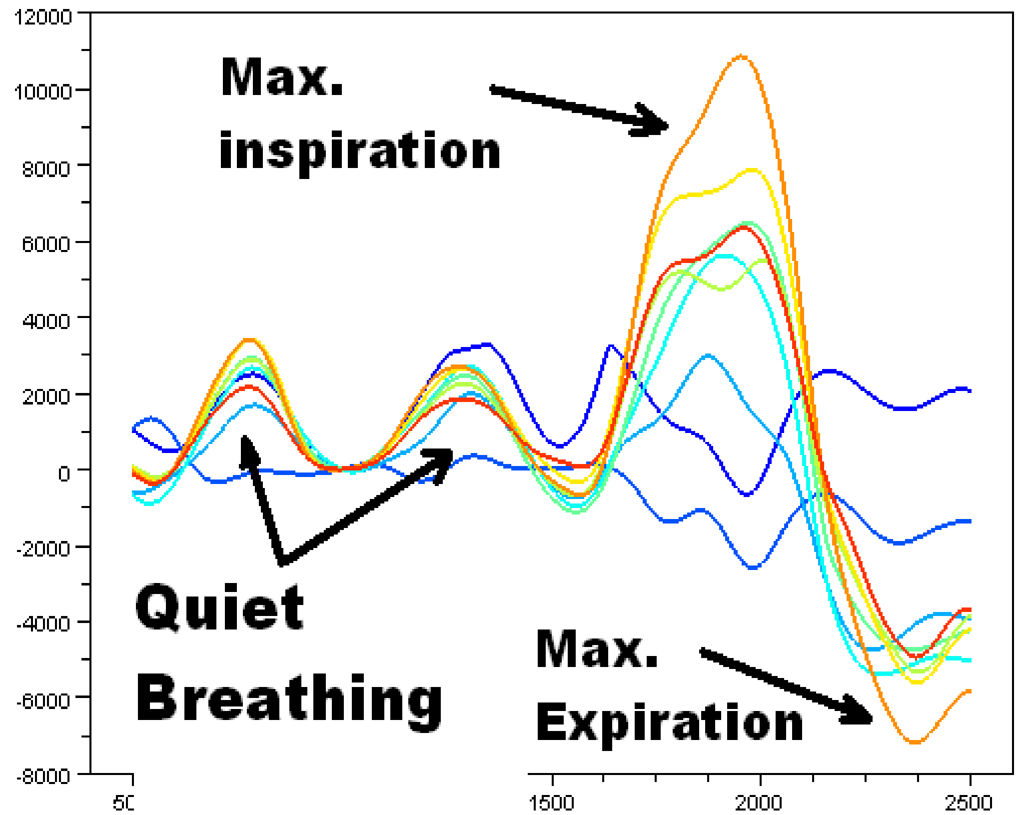
- Contributions made by the left and right sides were fairly symmetrical with a difference of 2% on average. Paired Test (p=0.21).

Spirometer (green) with OEP

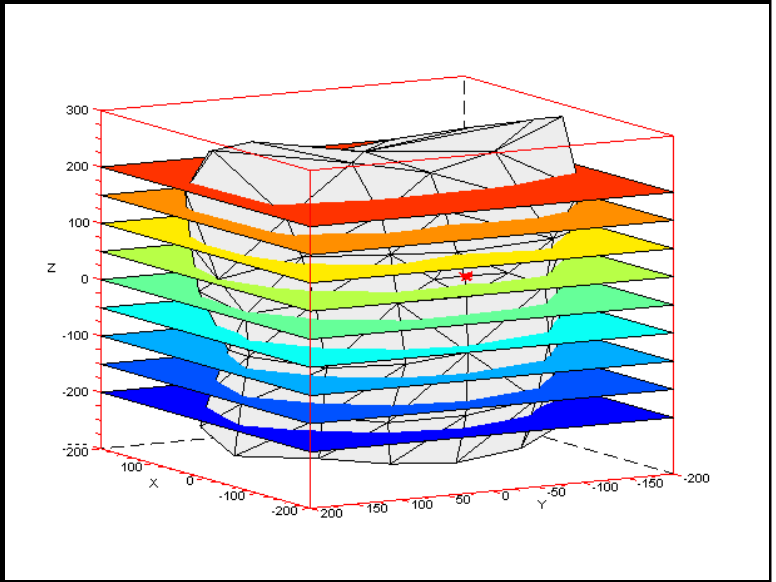


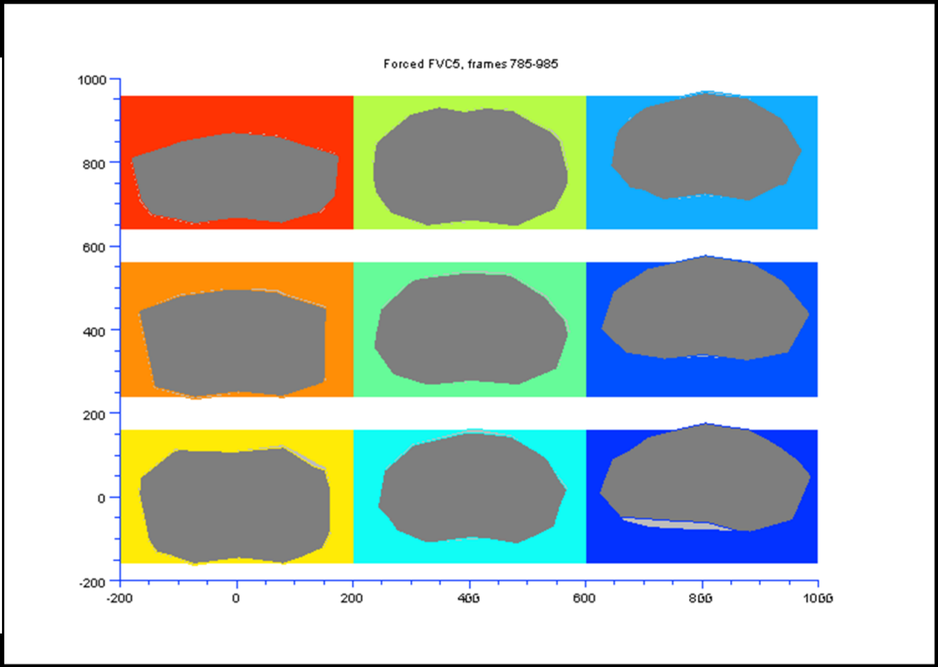
Cross Sectional Area Changes at Each Level Relative to FVC



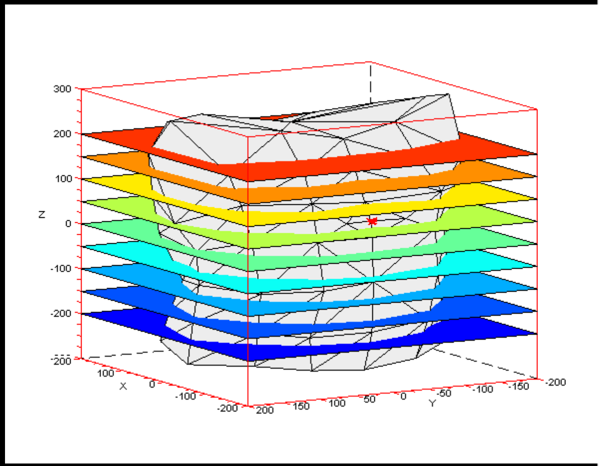


Quiet Breathing

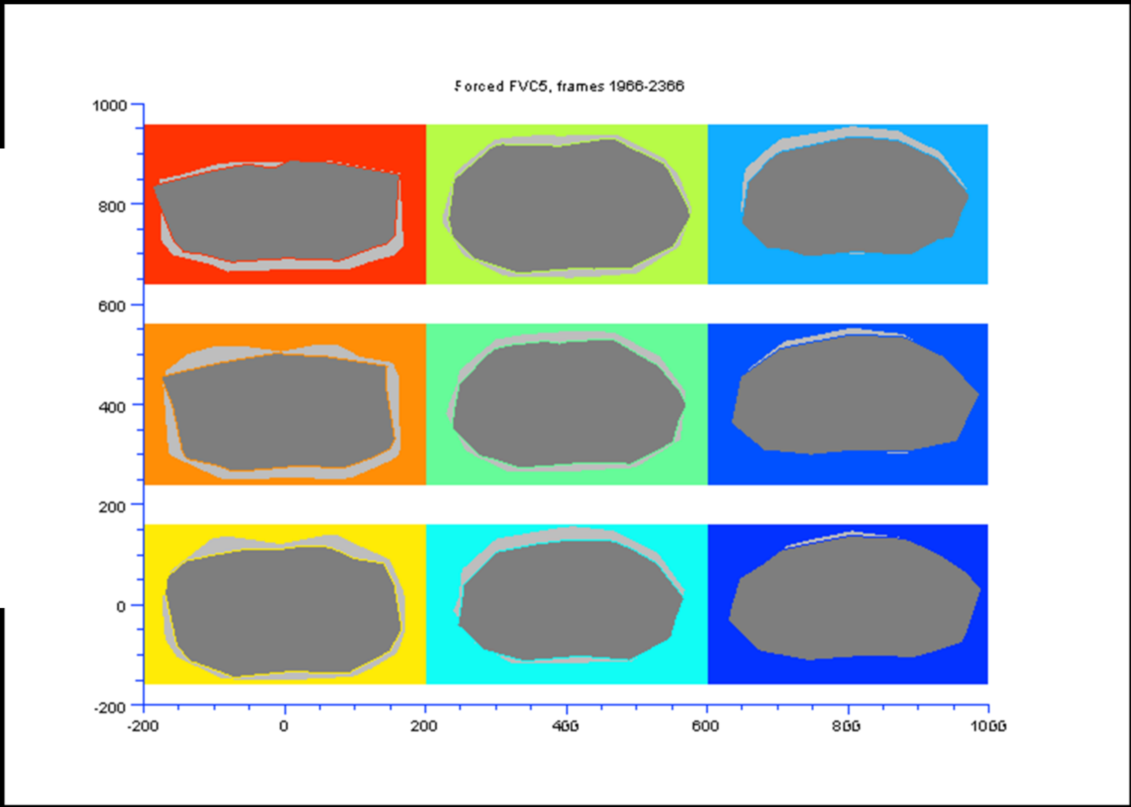




FVC



300
200
100
0
-100
-200
Z
X
Y



Forced FVC5, frames 1966-2366
1000
800
600
400
200
0
-200
-200
0
200
400
600
800
1000

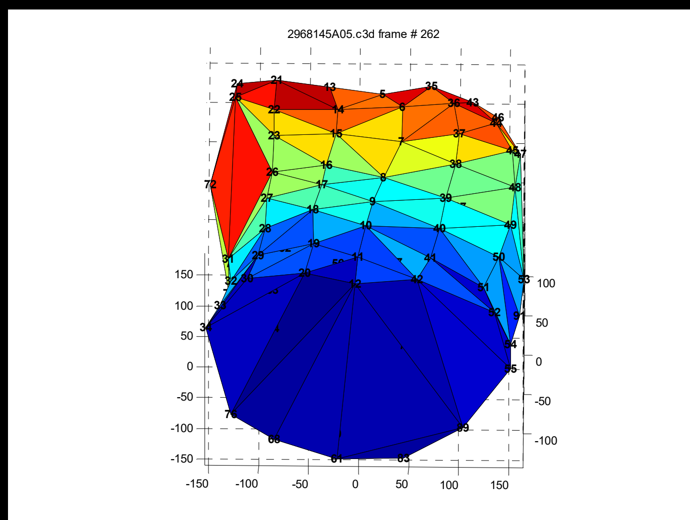
Discussion

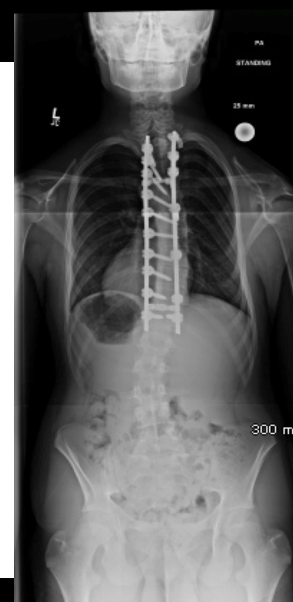
- AB > UT >LT (at rest)
- Early fusion of the UT segments more detrimental to PFT (Karol et al., 1996)
- Proximal thoracic fusions worse lung developement (Canavese et al., 2007)
- Motion of the AB section is correlated with diaphragmatic excursion in an ultrasound study (Wang et al., 2009)
- R & L thorax seem to contribute evenly. Consistent with adults using OEP (Tobin et al, 1986; Ferrigno et al., 1994; Cala et al., 1996; Aliverti et al., 2001)

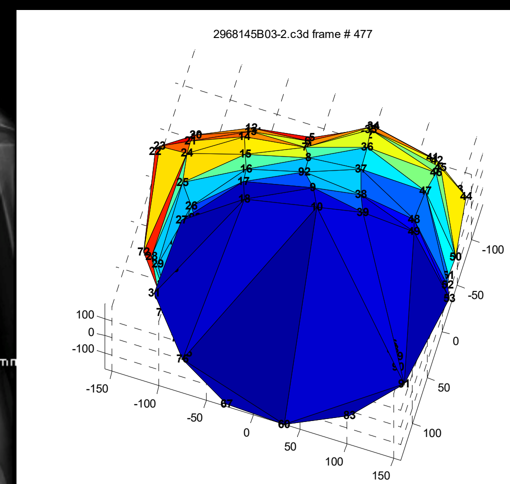
Limitations

- Only 12 subjects. However, results are very robust and consistent.

Prospective Study



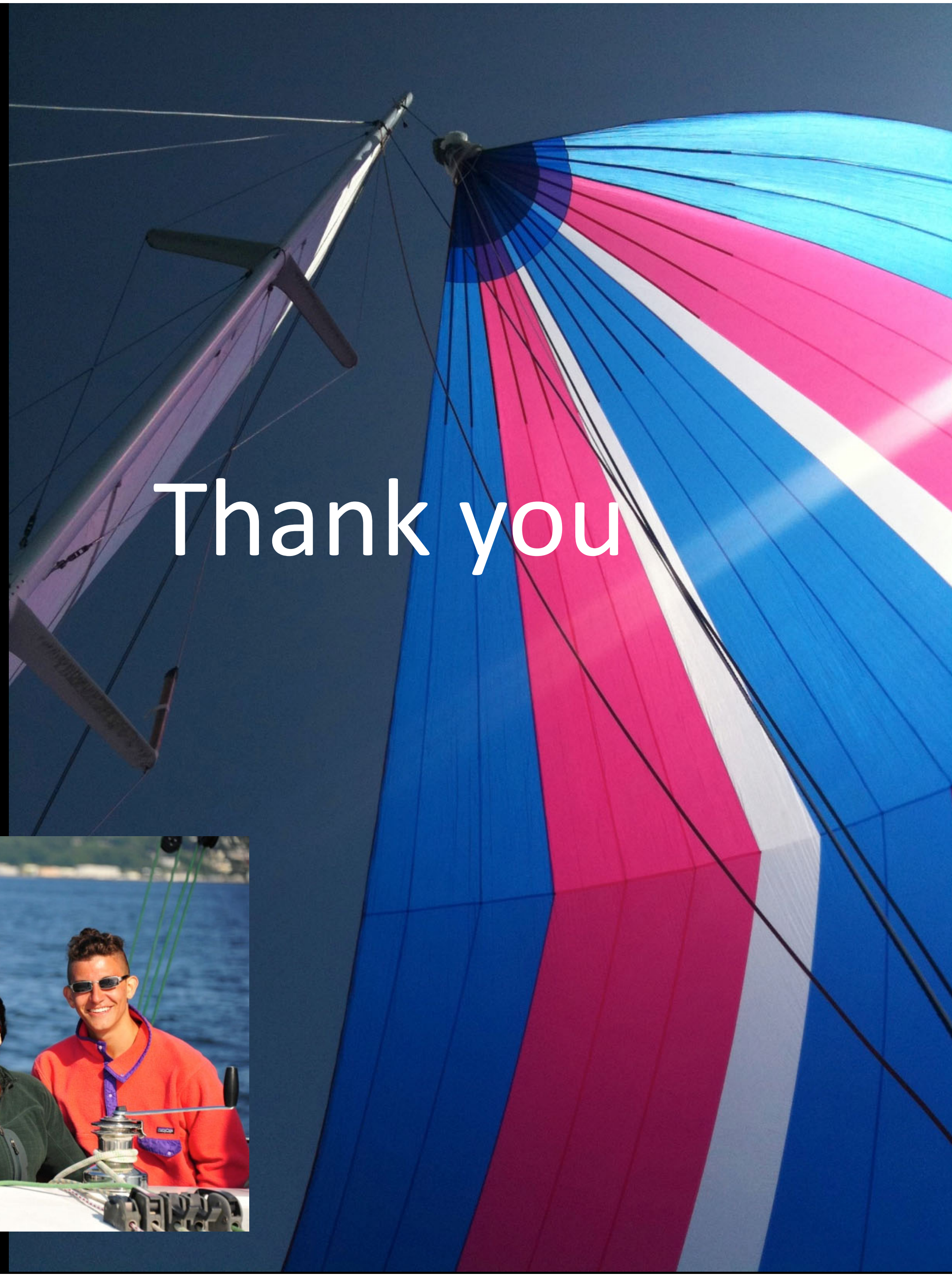




Adams FB view

Conclusions

- 3D chest wall analysis: non-invasive evaluation of thoracic or abdominal motion
- Measures tidal volume, total volume, in EOS patients unable to do PFT
- Reliable for future chest wall motion studies



Thank you

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