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Can non-contact measurement of tidal breathing using structured light plethysmography (SLP) distinguish COPD from health?

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INTRODUCTION

COPD threatens the lives of more than 3 million people every year (WHO, 2015) and reduces quality of life. Diagnosis of COPD relies on a number of factors including spirometry readings (*GOLD*, 2014). Spirometry is however sometimes not very well tolerated in the elderly and the very young. An assessment based on tidal breathing may therefore be desirable.

Structured light plethysmography (SLP) is a novel, non-contact technique that measures tidal breathing through estimating the displacement of the thoraco-abdominal (TA) wall. A structured grid of light is projected onto a subject's chest and abdomen and changes in the grid pattern are quantified over time. This provides a one dimensional signal corresponding to that subject's tidal breathing pattern.

We hypothesised that tidal breathing parameters measured using SLP can distinguish COPD patients from healthy subjects.

SUBJECTS AND METHODS

Clinical utility of SLP was examined in a cohort of 25 COPD patients and 25 healthy subjects matched for age, gender and BMI. The matching process was done to minimise the confounding factors.

Subjects were seated upright in a high-backed chair with their back supported.

The projected grid pattern was centered on the xiphisternum and adjusted to achieve maximum coverage of the anterior thoraco-abdominal wall. Five minutes of tidal breathing was acquired for each subject. Figure 1 shows how the SLP is used in practice.

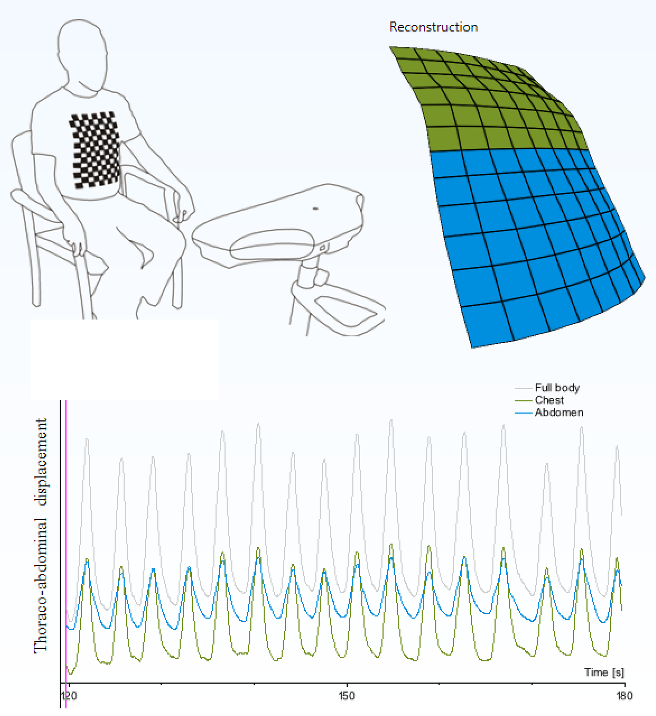

Figure 1. Working principle of SLP. Note that the TA wall is split into two sections one representing the chest and the other representing the abdomen. Average axial displacement of the surfaces corresponding to the chest and abdomen over time provides a means to generate one dimensional time series corresponding to the displacement of the chest and abdomen respectively. Using the regionalised signals one can then calculate regional tidal breathing parameters such as relative thoracic contribution and thoraco-abdominal asynchrony (TAA).

An age match was defined as an absolute difference of </= 5 years. BMI matches were based on BMI classification bands (BMI<18.5 underweight, 18.5<=BMI<25 Normal, 25<=BMI<30 overweight, and BMI>=30 obese).

TIDAL BREATHING PARAMETERS

Median and interquartile range (IQR) of 11 tidal breathing parameters of Respiratory rate (RR), Inspiratory time (tI), Expiratory time (tE) , Total breath time (tTot), tI/tE, tI/tTot (duty cycle),

% ribcage contribution, thoraco-abdominal asynchrony (TAA), time to peak tidal expiratory $flow_{SLP}$ over expiratory time ($tPTEF_{SLP}/tE$), time to peak tidal inspiratory $flow_{SLP}$ over inspiratory time ($tPTIF_{SLP}/tE$), $IE50_{SLP}$, were extracted from every detected breath. Figures 2 and 3 illustrate these indices.

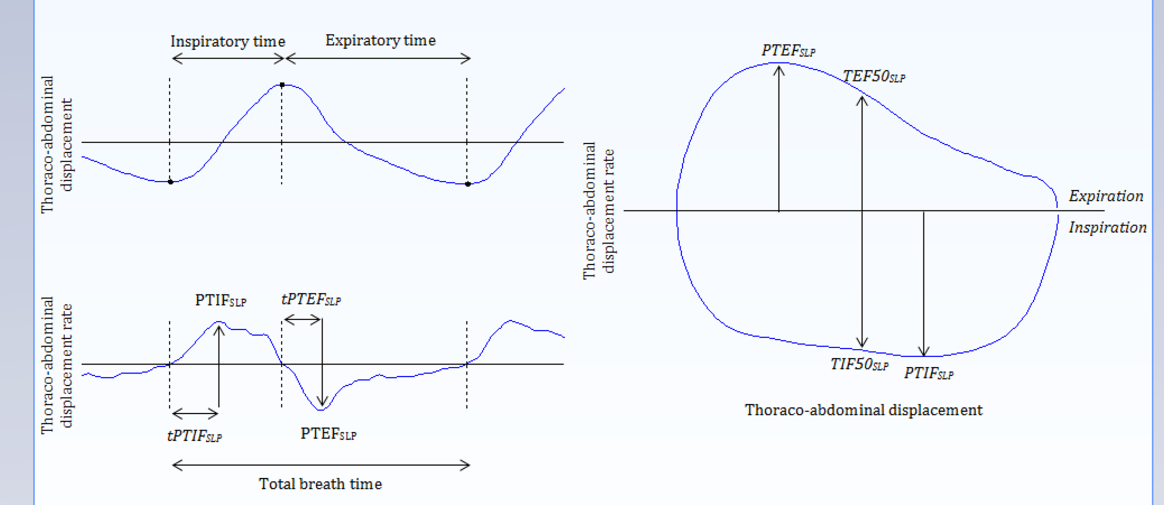

Figure 2. TA displacement and displacement rate signals are shown on the left graph. Tidal breathing timing indices as well as $tPTEF_{SLP}/tE$ and $tPTIF_{SLP}/tI$ are marked. Plotting TA velocity against TA displacement generates a loop analogous to a conventional tidal flow-volume loop, $IE50_{SLP}$ is given $TIF50_{SLP}/TEF50_{SLP}$ essentially quantifying the shape of the loop.

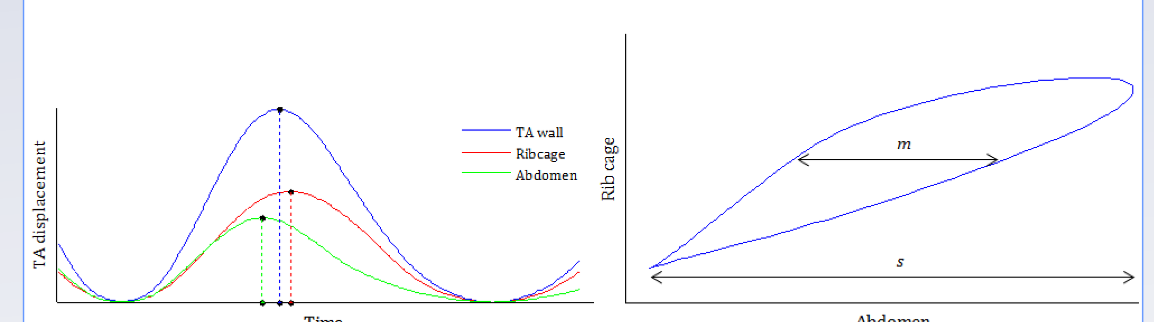

Figure 3. To calculate relative contribution of an arbitrary region A to an arbitrary region B, peak-to-peak amplitude of each breath from region A is divided by the peak to peak amplitudes of the corresponding breaths from region B. For TAA, displacement of ribcage is plotted against that of the abdomen. The shape of this graph provides an indication of the degree of asynchrony. TAA is specifically given as *arcsin(m/s)*.

RESULTS

The table below summarises how these tidal breathing parameters differ between COPD and healthy subjects. All the starred parameters retained their significance after accounting for multiple comparisons using the Benjamini-Hochberg procedure with 10% false discovery rate.

	Healthy		COPD		Significance (p-value)	
	Mean	SD	Mean	SD	p-value	
mRR	14.42	3.81	18.21	7.59	0.0305	*
vRR	2.66	1.46	3.3	1.82	0.1765	
mtI	1.74	0.51	1.35	0.34	0.0026	**
vtI	0.41	0.19	0.23	0.11	0.0002	***
mtE	2.8	1.37	2.37	0.92	0.1983	
v-tE	0.64	0.46	0.54	0.33	0.3701	
mtTot	4.57	1.82	3.71	1.2	0.0552	
vtTtot	0.84	0.49	0.69	0.37	0.2547	
mtI/tE	0.66	0.1	0.6	0.12	0.0627	
vtI/tE	0.17	0.06	0.13	0.04	0.0205	*
mtI/tTtot	0.39	0.04	0.37	0.04	0.0638	
vtI/tTtot	0.06	0.02	0.05	0.01	0.0790	
m%ribcage cont.	59.53	11.41	59.33	11.79	0.9533	
v%ribcage cont.	4.71	2.46	4.28	1.58	0.4674	
mTAA	4.93	1.9	8.03	6.72	0.0315	*
vTAA	5.48	1.8	5.9	2.93	0.5428	
$mIE50_{SLP}$	1.35	0.25	1.73	0.53	0.0024	**
$vIE50_{SLP}$	0.47	0.22	0.53	0.21	0.4018	
$mtPTEF_{SLP}/TE$	0.25	0.05	0.19	0.08	0.0046	**
$vtPTEF_{SLP}/TE$	0.14	0.06	0.08	0.05	0.0004	***
$mtPTIF_{SLP}/TI$	0.52	0.07	0.53	0.09	0.6188	
$vtPTIF_{SLP}/TI$	0.18	0.04	0.18	0.05	0.7680	

*** p<0.05, ** p<0.01, *** p<0.001**
Note: "m" stands for median and "v" stands for interquartile range (IQR), a measure of breath-by-breath variability. p-values are calculated using one way ANOVA.

CONCLUSIONS

Tidal breathing parameters measured using SLP can differentiate COPD from health. These results are inline with a previous study done using a pneumotachograph (Colasanti *et al.*, 2004). It is interesting that breath-by-breath variability in some of the parameters is more sensitive to the pathophysiology than the parameters themselves.

REFERENCES

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3. Colasanti, R. L., Morris, M. J., Madgwick, R. G., Sutton, L., & Williams, E. M. (2004). Analysis of tidal breathing profiles in cystic fibrosis and COPD. *Chest*, *125*(3), 901–908.