

Structured Light Plethysmography can quantify abnormal breathing in children aged 2-12 admitted with acute asthma

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ABSTRACT

SLP is a novel technique which measures breathing patterns by measuring chest and abdominal wall movements during tidal breathing (1). In this study we assessed the use of SLP to quantify differences in tidal breathing patterns in young children with acute asthma compared to normal children, and before and after bronchodilator treatment.

Children admitted to the ward with an exacerbation of asthma were recruited once they were clinically stable (n=39; age range 2-12 years). Five minutes of tidal breathing was recorded using SLP (Thora-3Di, PneumaCare Ltd) pre- and post-bronchodilator treatment. A matched group of children of similar age without asthma or diagnosis of respiratory illness were recruited (n=54) to generate comparative normal data. SLP can be used in young children with asthma to quantify clinically relevant tidal breathing parameters. Parameters differentiating the acute asthma group included higher IE50_{SLP} and TAA_{SLP} Phase

INTRODUCTION

Asthma, the single most common chronic disease during childhood starts very early in life in the majority of cases. Asthma is not a curable disease, however an early and accurate diagnosis and monitoring is very important for breathing assessment.

- Conventional techniques to measure lung function, such as spirometry, are challenging in young children, as the child's full cooperation is required to perform the test (2).
- Structured light plethysmography (SLP) is a novel technique which can be used to determine the parameters of tidal breathing in a non-invasive and zero-contact environment (Figure 1).

STUDY AIMS

This study assessed the use of SLP to quantify differences in tidal breathing patterns in young children with acute asthma compared to normal children, and before and after bronchodilator treatment in the asthmatic group.

METHODOLOGY

- Children admitted to the ward with an exacerbation of asthma were recruited once they were clinically stable (n=39; age range 2-12).
- Five minutes of tidal breathing was recorded using SLP (Thora-3Di, PneumaCare Ltd) pre- and post-bronchodilator treatment.
- A matched group of children of similar age without asthma or diagnosis of respiratory illness were recruited (n=54) to generate comparative normal data.
- Clinically relevant tidal breathing parameters such as respiratory rate (RR), duty cycle (tI/tTot) were obtained from the movement-time signal.
- Flow measured by SLP is defined as the rate of change of the movement signal, and is calculated as the first derivative of the movement-time signal.
- The ratio of inspiratory to expiratory flow at 50% of tidal movement (TIF50_{SLP}/TEF50_{SLP}) which is referred to as IE50_{SLP} was obtained from Flow-movement loops.
- Relative Ribcage contribution to total movement %RC_{SLP} was quantified by dividing peak-to-peak amplitude of each breath from RC by the peak-to-peak amplitude of the total TA movement of the corresponding breath (Figure 2).
- TAA_{SLP} (Thoraco-abdominal asynchrony) which describes temporal movement of ribcage to abdomen, was calculated using the method of Konno and Mead (3).

For each subject, breathing parameters were calculated. Median (prefix 'm') was used to provide a measure of parameter magnitude and 'v' to denote within subject variability (i.e. calculated using interquartile range [IQR]).

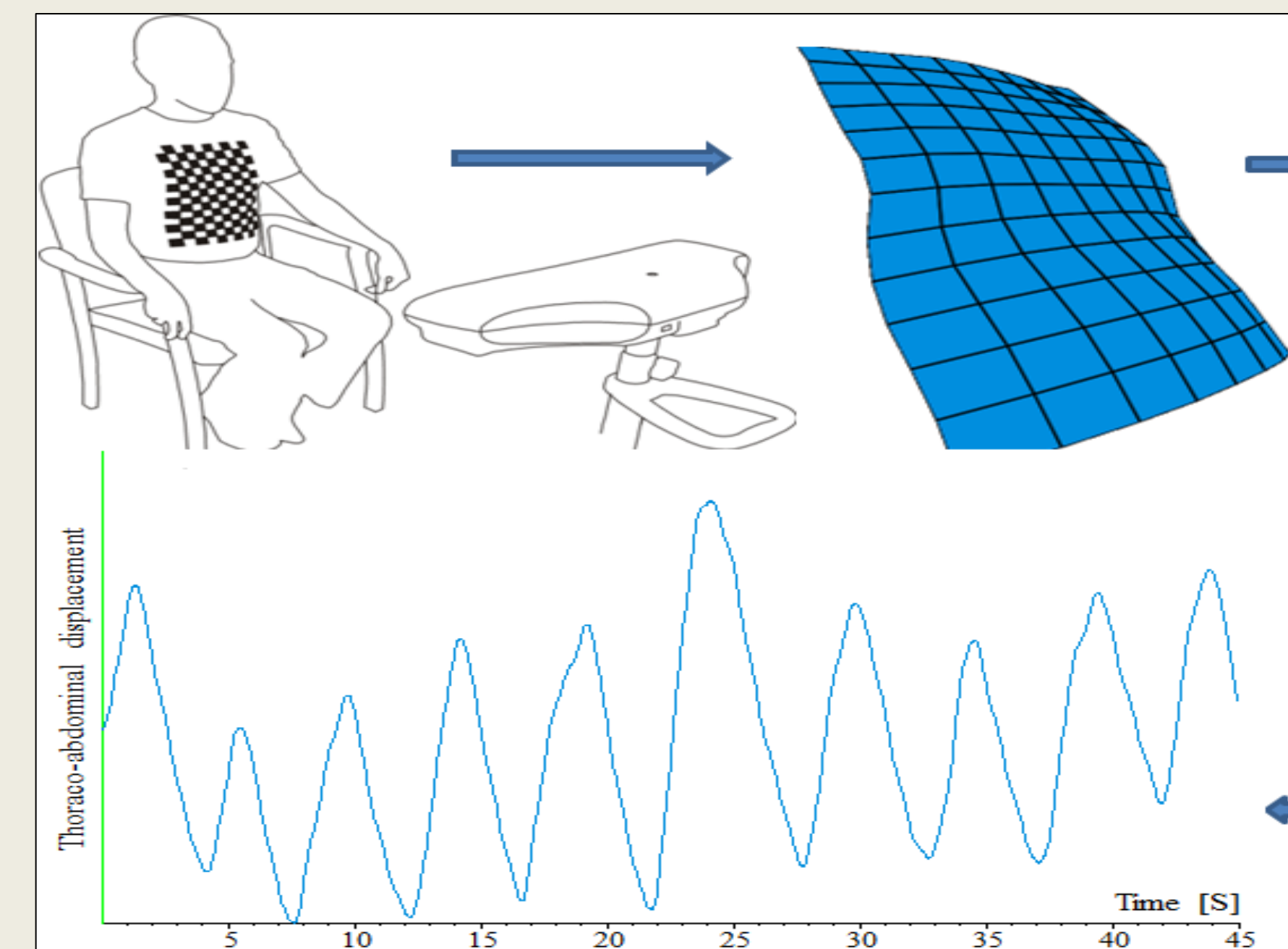


Figure 1: Structured Light projected onto the thoraco-abdominal (TA) wall of a participant seated approximately 1 meter from the device (Thora-3Di™, PneumaCare, Cambridge, UK). And the 3D-Reconstruction of the projected area with the tidal respiratory breathing trace.

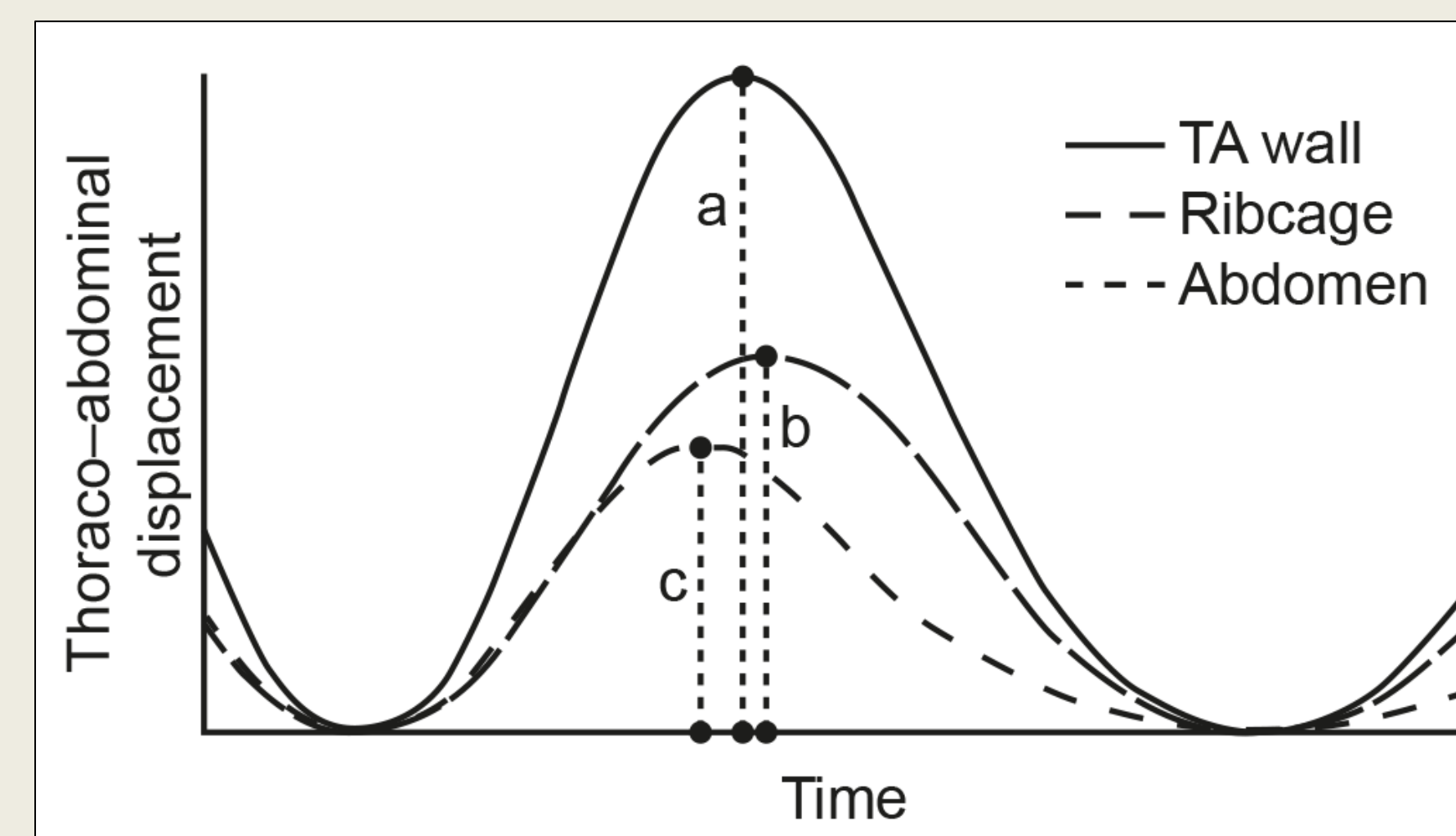


Figure 2: Thoraco-abdominal (TA) displacement of a single breath and its thoracic and abdominal components as measured by structured light plethysmography.

RESULTS

- Each SLP parameter and its variability was compared between healthy children and those with asthma (pre-bronchodilator) using a Mann-Whitney-U test. The paired Wilcoxon signed-rank test was used to assess the effect of bronchodilator in children with asthma.
- mIE50 was higher in the acute asthma group (1.47 vs. 1.31, P=0.002). However, there was no-significant reduction as a response to bronchodilator (1.47 vs. 1.5, P=0.477).
- Differences in within-subject variability were apparent in the asthma group. vtI, vtE, vtTot, vtPTIF/tI were lower (all p<0.001).
- variability of Thoraco-abdominal asynchrony vTAA_{SLP} was higher in the asthma group (p<0.001). The only variability parameter that responded to a bronchodilator was vtPTEF/tE (0.21 pre vs. 0.15 post, p<0.001).

Parameters	Healthy children		Children with acute asthma (before bronchodilator)		Z-statistics	Significance (MWU test)
	Median	IQR	Median	IQR	z	p-value
Timing indices and ratios						
mRR	23	5.35	30	7.7	-4.74	<0.001
vRR	4.57	2.95	4.45	3.15	0.11	0.913
mtI/tTot	0.42	0.04	0.41	0.04	1.2	0.229
vtI/tTot	0.07	0.02	0.05	0.03	3.37	0.001
Movement- and time-derived parameters						
mIE50 _{SLP}	1.31	0.3	1.47	0.4	-3.13	0.002
vIE50 _{SLP}	0.6	0.32	0.56	0.4	1.01	0.313
mtPTEF _{SLP} /tE	0.34	0.09	0.38	0.18	-1.76	0.079
vtPTEF _{SLP} /tE	0.22	0.09	0.21	0.2	0.14	0.885
Regional parameters (relative contribution and phase)						
m%RC _{SLP}	41.01	14.47	42.86	20.68	-0.77	0.439
v%RC _{SLP}	9.22	6.82	10.13	7.39	-0.6	0.551
mTAA _{SLP}	11.88	9.83	40.16	43.55	-5.41	<0.001
vTAA _{SLP}	13.53	12.97	24.08	14.7	-4.21	<0.001

Table 1: SLP-assessed tidal breathing parameters in children with acute asthma (before bronchodilator administration) versus healthy children.

Parameters	Children with acute asthma (before bronchodilator)		Children with acute asthma (after bronchodilator)		Z-statistics	Significance (WSR test)
	Median	IQR	Median	IQR	z	p-value
Timing indices and ratios						
mRR	30	7.7	31.03	8.24	-1.56	0.118
vRR	4.45	3.15	4.36	2.84	-0.47	0.635
mtI/tTot	0.41	0.04	0.41	0.04	0.97	0.331
vtI/tTot	0.05	0.03	0.05	0.02	1.31	0.189
Movement- and time-derived parameters						
mIE50 _{SLP}	1.47	0.4	1.5	0.32	0.71	0.477
vIE50 _{SLP}	0.56	0.4	0.52	0.36	1.84	0.065
mtPTEF _{SLP} /tE	0.38	0.18	0.37	0.14	0.85	0.395
vtPTEF _{SLP} /tE	0.21	0.2	0.15	0.12	3.87	<0.001
Regional parameters (relative contribution and phase)						
m%RC _{SLP}	42.86	20.68	39.47	19.85	1.95	0.051
v%RC _{SLP}	10.13	7.39	8.98	4.58	1.45	0.147
mTAA _{SLP}	40.16	43.55	31.08	39.26	0.89	0.372
vTAA _{SLP}	24.08	14.07	20.31	14.56	1.41	0.159

Table 2: SLP-assessed tidal breathing parameters in children with acute asthma before and after bronchodilator administration

CONCLUSIONS

SLP can be used in young children to acquire and quantify clinically meaningful measures of tidal breathing and was able to quantify abnormalities in tidal breathing patterns in young children with acute asthma. Parameters differentiating the acute asthma group included higher IE50_{SLP} and TAA_{SLP} Phase.

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