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Thoracoabdominal asynchrony correlates with peripheral vascular resistance changes in a cohort of obese children

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Abstract

Objective: The purpose of this study was to assess the relationship between the thoracoabdominal asynchrony (phase angle), as an index of inspiratory airflow resistance, pulse transit time arousal index (PTT Ar/I), as changes in peripheral vascular resistance and intrathoracic pressure, and obstructive apnea index (OA), Oxygen Desaturation Index (ODI), snoring (% estimated Total Sleep Time - eTST) and apnea-hypopnea index (AHI) in a cohort of exogenous obese children.

Material and Methods: Body mass index (BMI) and BMI z-scores were calculated according to age and sex in 36 consecutive obese children. Nasal patency, tonsil size, Friedman palate position scoring were also recorded. An overnight sleep respiratory recording was performed using an polygraphic ambulatory device.

Results: Subjects studies had normal to mild sleep respiratory involvement (assessed by respiratory polysomnographic scoring). Phase angle correlated significantly with PTT Ar/I, but not with AHI (n/hr), OA (n/hr), ODI (n/hr) and snoring (% eTST), even adjusting for nasal patency, tonsil hypertrophy, palate position and BMI (z-score).

Conclusion: Thoracoabdominal asynchrony (phase angle) is correlated with peripheral vascular resistance changes (PTT Ar/I), suggesting a subclinical upper respiratory airflow anomaly with autonomic activation in obese subjects.

Keywords: Phase angle, Pulse transit time, Obesity, Children, Overnight Respiratory polygraphy.

Introduction

Childhood obesity has an impact on obstructive sleep apnea (OSA). Obesity can result in reduced lung volume and decreased upper airway caliber (1). The prevalence of OSA is significantly higher in obese children, with or without adenotonsillar hypertrophy, compared to non-obese counterparts (2) . In particular, the obesity level remains an important aggravating factor for OSA and reduced pulmonary function (3). Adenoid size is also important in obese children with symptoms of sleep disordered breathing (SDB), due to its strong association with the presence of OSAS (4).

The gold standard for diagnosing OSA is overnight polysomnography (PSG). In addition, a poligraphic device has been reported to be an acceptable and cost-effective alternative to PSN (5, 6). In obese children, home and sleep laboratory overnight PSGs have shown good agreement (7).

Phase angle vector analysis is an index of thoracoabdominal asynchrony (TAA) and inspiratory airflow resistance. An increased value suggests an increased inspiratory work of breathing.

Phase angle vector analysis it is claimed as a useful parameter of impending upper airway obstruction (8). In particular, an increase in inspiratory resistance, as observed during obstructive apnea (OA) and hypopnea (H), produces an asynchrony between rib cage and abdomen (9).

Pulse Transit Time (PTT) is the time taken for the arterial pulse to travel from the heart to the pulse oximeter site (finger or toe). PTT analysis is calculated from the electrocardiogram (ECG) signals and the plethysmographic waveforms from the pulse oximeter (10). PTT has been suggested as a non-invasive index which reflects changes in peripheral vascular resistance and intrathoracic pressure. PTT arousal index (PTT Ar/I) is the frequency (number/hr) of a defined decrease in PTT, which may serve as a marker for respiratory events that occur in patients with OSA (11).

The purpose of this study was to assess the relationship between the TAA (phase angle), as an index of inspiratory airflow resistance, PTT Ar/I, as changes in peripheral vascular resistance and intrathoracic pressure, and AHI in a cohort of 36 obese children without declared respiratory sleep disturbance.

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Material and Method

Study population

A prospective respiratory sleep study was carried out in 36 consecutive obese children referred by pediatricians to our department that specializes in endocrine disorders between June 2014 and June 2015.

Inclusion criteria were exogenous obesity, normal to mild sleep respiratory involvement (according to polysomnographic scoring). Exclusion criteria were: craniofacial abnormalities, chromosomal disorders, lung disease, neuromuscular disorders, central apnea or central hypoventilation, endocrine disorders and genetic diseases related to obesity. Allergy and restless leg syndrome were excluded by interview at admission. None of the studies subjects were involved in any diet restriction program.

Caregivers signed an informed consent document prior to enrollment in the study. The protocol was approved by the Institutional Ethics Committee of Verona.

Anthropometry and clinical scoring

All measurements were taken in the morning after an overnight fast with patients wearing only underwear. Height and weight were measured by skilled personnel using standardized techniques. Body mass index (BMI) and BMI z-scores were calculated according to age and sex (http://nccd.cdc.gov/dnpabmi/Calculator.aspx).

Nasal patency was assessed according to published criteria (12). Unilateral and bilateral nasal obstructions were quoted equally from 0 (unoccluded) to 3 (completely occluded). The tonsils were measured using a grading system from 1 to 4 (13). The palate position was measured using a grading system from 1 to 4 (14).

Overnight respiratory polygraphy

An overnight respiratory polygraphic study was performed using a portable ambulatory device (SOMNOscreenTM PSG, SOMNOmedics GmbH, Randersacker, Germany), with continuous monitoring of nasal airflow, chest and abdominal respiratory movements (thoracic and abdominal belts), arterial oxygen saturation (SaO2; digital pulse oximetry), ECG, body position (mercury sensor) and tracheal sounds (microphone).

The device was applied between 8:00 PM and 08:00 AM with an overnight recording. All subjects lasted for $\geqslant$6 h in a quiet, specifically prepared sleep room.

Analysis of the entire recording was carried out both manually and automatically (DOMINO software, Somnomedics v.2.6.0). The estimated total sleep time (eTST) was calculated according to published criteria, and movement periods were excluded (15).

Respiratory events were scored according to the American Academy of Sleep Medicine guidelines (16). The number of OA plus mixed apneas (M) plus central apneas (CA) and H was divided by hours of eTST (n/hr) and expressed as an index (AHI) (17). Desaturation was considered in the presence of a drop $\geqslant$ 3% in oxygen. The oxygen desaturation index (ODI) was calculated as the total number of desaturations divided by the eTST (n/hr). Snoring (% of eTST) was also recorded.

As an index of inspiratory effort, phase angle is vector of rib cage and abdominal respiratory movements recorded during natural nocturnal active and quiet sleep. Phase angle analysis determined the degree of obstruction calculated from the 2 effort signals (thoracic and abdominal belts).

PTT analysis was calculated from the ECG signals and the plethysmographic waveforms from the pulse oximeter.

Statistical analysis

Statistical analysis was done using SPSS Statistics 19.0 software for Windows. Descriptive statistics (mean, standard error and range) were calculated for the quantitative variables considered in this study. The strength of the association between two variables (snoring versus respiratory variables or versus clinical scoring) was evaluated by calculating simple and partial correlation coefficients, adjusting for clinical scoring when appropriate. Statistical significance was considered for $P<0.05$.

Results

Thirty-six obese children (17 males) were enrolled in the study. Physical characteristics (mean +/- SD) were showed in Table 1. Scoring for nasal obstruction, tonsils hypertrophy and palate position (% in the population study) were calculated and showed in Table 1. Sleep respiratory polysomnographic results are summarized in Table 2.

Correlation coefficients (r) between phase angle (degrees) and respiratory polysomnographic results are shown in Table 2. Phase angle correlated significantly with PTT Ar/I ($P<0.005$), even after adjusting for nasal patency, tonsil hypertrophy, palate position, or BMI (Z-score), but not with AHI and ODI. Figure 1 shows the correlation (mean and 95% C.I.) between phase angle and PTT Ar/I (obese children with AHI > 1.4/hr are shown as non-filled squares.

Table 1: Physical properties of subjects and standards

	Mean +/- SD
Age (year)	11.9+/- 2.6
Weight (kg)	72.6+/-21.7
Height (cm)	154+/-14
BMI z-score	2.17+/-0.28
	Standards %
Scoring for nasal obstruction	0=47.2% 1=13.9% 2=13.9% 3 and 4=25%
Tonsils hypertrophy	1=61.1% 2=27.8% 3=11.1%
Palate position	1=44.4% 2=41.7% 3=8.3% 4=5.6%

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Table 2: Correlation analysis between snoring and sleep cardio-respiratory parameters

Dependent variable	Independent variables	Mean+/- SD	R*	p value*
Phase angle (degree)		35.7+/-11.7	-	-
	OA (n/hr)	0.18+/- 0.3	0.080	0.644
	AHI (n/hr)	0.18+/- 0.9	0.129	0.454
	ODI (n/hr)	0.8+/-0.9	0.194	0.386
	Snoring (% eTST)	3.4+/-7.9	0.056	0.745
	PTT Ar/I	74.1+/-18.7	**0.497**	**0.002**

* Similar results were obtained even adjusting (partial correlation analysis) for nasal patency or tonsil hypertrophy, or palate position or BMI (Z-score), and nasal patency & tonsil hypertrophy & palate position, and nasal patency & tonsil hypertrophy & palate position and BMI (Z-score).

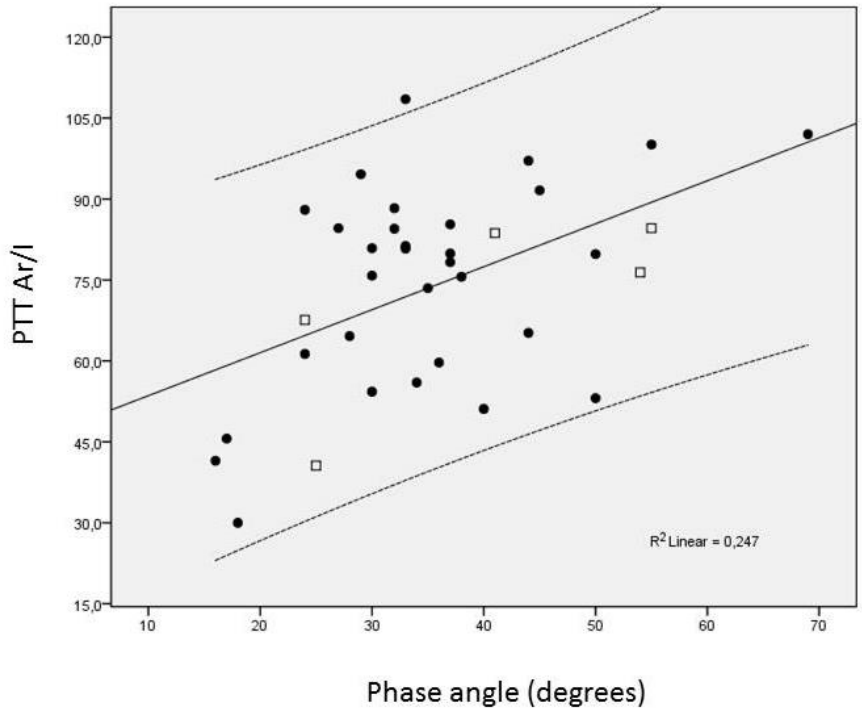

Figure 1: Correlation (mean and 95% C.I.) between phase angle and PTT Ar/I (obese children with AHI > 1.4/hr are shown as non-filled squares).

Discussion

The major finding of the present study was that the TAA (phase angle), as the inspiratory airflow resistance measure, correlated significantly with peripheral vascular resistance changes (PTT Ar/I) (R2=0.25; p<0.005) in our group of obese children with normal to mild AHI (0.8±0.9 events/hr).

A pathophysiological explanation regarding the relationship between phase angle and PTT can be put forward. A compromised upper airway patency leads to an increased inspiratory work of breathing which, on turn, may lead to a change of intrathoracic pressure and TAA (increased phase angle) values. Moreover, the non-invasive PTT index, as an alternative to esophageal manometry, can assess the changes of intrathoracic pressure (17). PTT Ar/I was also found to be elevated in children manifesting episodic subcortical arousals, resulting from obstructive respiratory events compared with children with primary snoring (17). Finally, PTT has been referred as a sensitive parameter of respiratory events (11). Thus, phase angle and PTT Ar/I values are linked to the same compromised upper airway patency.

In our obese patients, the TAA (phase angle) correlated positively with PTT Ar/I. Therefore, phase angle and PTT Ar/I did not correlate with AHI.

They were classified as having normal to mild sleep respiratory involvement. A possible explanation is that we detected an ample subclinical sleep respiratory involvement in our patients, with phase angle and PTT Ar/I as more sensitive markers than AHI.

The prevalence of OSA in obese children is high (37.1%) (18). Notably, enlarged tonsil and adenoid size increases the risk of OSA (19-24). Moreover, obesity itself has been suggested as a risk factor for OSAS (2), in combination with snoring and adenotonsillar hypertrophy (25). Interestingly, obese severity and ethnicity were associated with OSAS, but not with tonsillar size and palate position (26). Obese children with OSA might continue to have breathing difficulties even after adeno-tonsillar surgery, and this was explained by abnormalities of pulmonary mechanics related to obesity that may cause problems of gas exchange during sleep (1). Although larger adenotonsillar enhance the chance of having SDB, it does not predict the severity of AHI, but reflects flow limitation in children with mild to severe OSAS (27). However, minor changes in adenotonsillar dimensions give an equivalent severity of upper airway obstruction. Soft-tissue changes and fat deposition in the upper airways have both been involved in predisposing the upper airways to collapsibility during sleep (28, 29).

In our study involving obese children with normal to mild AHI, the relationship between phase angle and PTT Ar/I was not modified after adjustment for physical parameters, such as tonsil grading, palate position, nails patency and fatness. This may underpin that the individual characteristics of the upper airway morphology in obese children can predispose to their collapsibility during sleep, thus causing changes in upper respiratory airflow and peripheral vascular resistance. However, further studies are necessary in obese children with normal to mild sleep respiratory disturbances having higher sleep TAA and PTT Ar/I to clarify their clinical significance, if this disturbance anticipate the development of further overt sleep respiratory disturbances and cardiovascular problems, and if diet intervention (i.e., weight reduction) is capable to normalize this pattern.

Limitations of the study include: i) Our in-hospital monitoring was done in an unfamiliar environment. ii) We did not evaluate the sleep efficiency but respiratory sleep characteristics; iii) We did not evaluate adenoid size, since this required nasal fibroscopy or radiology. Conversely, the strengths of the study are: i) Obese children referred to our department were not referred because of sleep respiratory problems; ii) The measurements of sleep respiratory patterns were performed instrumentally, but not investigated by interview in an out-patient setting. This gave precise quantitative data; iii) The clinical parameters used are quite affordable in the clinical setting.

Conclusion

In conclusion, we want to emphasize that we investigated the sleep respiratory characteristics of exogenous obese children unselected for reporting respiratory sleep problems. TAA (phase angle) and related peripheral vascular resistance changes (PTT Ar/I) can detect a subclinical upper respiratory airflow anomaly with autonomic activation in some obese patients at enhanced risk for respiratory sleep problems. Further longitudinal studies may be able to uncover the clinical significance and consequences of early intervention aimed at reducing fatness to achieve normalization of the respiratory pattern herein reported.

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Ethical issues: All Authors declare, Originality and ethical approval of research, and responsibilities of research, responsibilities against local ethics commission are under the Authors responsibilities. The study was conducted under defined rules by the Local Ethics Commission guidelines and audits.

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