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SCIENTIFIC INVESTIGATIONS

# Interpreting CPAP device respiratory indices in children

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**Study Objectives:** An increasing number of children with obstructive sleep apnea (OSA) require treatment with continuous positive airway pressure (CPAP). This study aimed to determine whether automatic respiratory indices from a CPAP device accurately predict manually determined respiratory indices derived from overnight polysomnography (PSG) in children.

**Methods:** Consecutive children undergoing manual CPAP titration PSG using a ResMed VPAP ST-A (S9) were included. The apnea-hypopnea index (AHI), apnea index (AI), and hypopnea index (HI) from automatic analysis of the CPAP device for that night ($AHI_{CPAP}$, $AI_{CPAP}$, and $HI_{CPAP}$) were compared with manually derived respiratory indices ($RDI_{PSG}$, $OAHI_{PSG}$, $AI_{PSG}$, and $HI_{PSG}$) using the Wilcoxon matched-pairs signed-ranks test.

**Results:** Forty-six children (32 boys; median age, 13.5 years; range, 4.6–20.0 years) were included. There was no difference between $RDI_{PSG}$ and $AHI_{CPAP}$ ($P$ = .6) nor between $HI_{PSG}$ and $HI_{CPAP}$ ($P$ = .2). $AI_{PSG}$ was significantly lower than $AI_{CPAP}$ (mean difference −1.3 events/hr, $P$ < .001). $AI_{PSG}$ and $AI_{CPAP}$ were strongly correlated ($r^2$ = .72, $P$ < .01), but the CPAP machine overestimated the number of apneas at higher AIs. $OAHI_{PSG}$ was significantly lower than $AHI_{CPAP}$ ($P$ = .003) but strongly correlated ($r^2$ = .87, $P$ < .01). The CPAP device significantly underestimated the number of hypopneas at higher indices. Using the manually scored $OAHI_{PSG}$ of ≥5 events/hr to define significant residual OSA, the $AHI_{CPAP}$ had a high specificity (0.95) but low sensitivity (0.20).

**Conclusions:** The ResMed S9 respiratory indices are not accurate enough to guide treatment decisions in children; in particular, they do not rule out the presence of residual OSA in children that remain symptomatic on CPAP. A low $AHI_{CPAP}$ is reassuring in the context of a stable patient but may miss ongoing hypopneas.

**Keywords:** continuous positive airway pressure, sleep apnea, treatment, child

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**BRIEF SUMMARY**

**Current Knowledge/Study Rationale:** Continuous positive airway pressure is an increasingly used treatment for obstructive sleep apnea in children. Continuous positive airway pressure machines report automatically generated respiratory indices while a patient is on treatment, but the utility of these compared with polysomnography in detecting residual obstructive sleep apnea in children has not been investigated.

**Study Impact:** This study shows significant differences in the indices generated by a continuous positive airway pressure device compared with the current gold standard of a manually scored polysomnography study. In particular, automatically generated indices do not rule out the presence of residual obstructive sleep apnea and may miss untreated hypopneas. Knowledge of how automated reports compare with traditional methods of determining residual obstructive sleep apnea will inform the clinical use of these reports in pediatric patients.

## INTRODUCTION

Obstructive sleep apnea (OSA) is a common condition of childhood, characterized by recurrent episodes of upper airway obstruction during sleep. Most children with OSA are treated with adenotonsillectomy, but an increasing number require treatment with continuous positive airway pressure (CPAP).[1] Equipment improvements, particularly in the range of masks available for young children, have made this therapy possible for infants and children of any age. CPAP machines are the same as those used in adults, with internal algorithms designed and tested with adults in mind.

Modern CPAP machines provide usage reports that detail ongoing persistence of obstructive events while treatment is being delivered, with respiratory events detected by proprietary algorithms. Such indices could help guide the need for changes to treatment over time such as a need for increased pressure. In studies of adult patients, these indices typically demonstrate good correlation with indices derived from traditional scoring by a trained sleep technologist; however, levels of agreement vary and are likely dependent on the brand and model of devices used.[2–8] One previous study in children using limited channel sleep studies found that a CPAP device overestimated the apnea-hypopnea index (AHI) in children, mainly because of inappropriate scoring of central apneas.[9]

In this study, we aimed to determine how the automatic respiratory indices provided by a CPAP device compare with manually determined respiratory indices during a night of in-laboratory polysomnography (PSG) in a child. Knowledge of how automated reports compare with traditional methods of determining residual OSA would inform the clinical use of these reports in pediatric patients.

## METHODS

Data were collected for all children who attended the Melbourne Children's Sleep Centre for CPAP titration PSG from

May 2017 to July 2018. Demographic and treatment details were collected from the medical record, and CPAP data from the night of the PSG were downloaded from the CPAP device used in the sleep laboratory. Parents gave consent for their child's data to be included in this study. The study was approved by the Monash Health Human Research Ethics Committee.

### PSG studies

All children underwent attended overnight PSG performed in the sleep laboratory for titration of CPAP pressure. All patients had been on CPAP at home before the PSG, either for an acclimatization period early in CPAP treatment where the goal of the study was determining the optimal treatment pressure, or having been on treatment at home where the goal of the study was to confirm the adequacy of the current prescribed pressure with growth or change in clinical condition. Our protocol for starting CPAP has been described in detail elsewhere.[10] The following parameters were measured, using a commercially available PSG system (Grael system, Compumedics, Melbourne, Australia): electroencephalograms (central, frontal and occipital), left and right electrooculograms, mental-submental and left and right tibial electromyograms, continuous electrocardiogram, body position, and infrared video. Respiratory effort was assessed using uncalibrated respiratory inductance plethysmograhy (z-RIP belts, Pro-Tech Services, Inc., Mauklteo, WA). Oxygen saturation was measured by pulse oximetry using a 2-second averaging time (Masimo Corporation, Irvine, CA), and transcutaneous carbon dioxide was measured using a Sentec Digital Monitoring System (Sentec AG, Therwil, Switzerland). The flow signal used for definition of events was the flow signal derived from the CPAP machine, as recommended by American Academy of Sleep Medicine guidelines.[11] A line connected to a pressure transducer was also connected as close to the mask as possible[12] as an additional indicator of obstructed airflow. Leak was also quantified by the CPAP machine and recorded continuously to the PSG via direct current input.

CPAP was manually titrated by an experienced sleep technologist using the ResMed VPAP ST-A with iVAPS (S9) device set in CPAP mode with EasyCare remote software and TX Link (ResMed, Sydney, Australia). Starting pressure ranged from 4 to 16 $cmH_2O$ as instructed by the referring physician, and pressure titration otherwise followed the American Academy of Sleep Medicine Clinical Guidelines for children,[12] with the goal of eliminating all obstructive events and minimizing respiratory event–related arousals, work of breathing, and snoring.

### PSG scoring criteria

All PSGs were scored by sleep technologists trained in pediatric sleep scoring. Sleep studies were scored following the American Academy of Sleep Medicine criteria,[11] and all respiratory events were ≥2 respiratory cycles in duration. The optimal CPAP treatment pressure was determined by the referring sleep physician based on interpretation of the CPAP titration PSG.

The following respiratory indices were calculated from the PSG: respiratory disturbance index ($RDI_{PSG}$), which included all respiratory events scored on the PSG (central and obstructive); obstructive apnea-hypopnea index ($OAHI_{PSG}$), which included all obstructive events, including obstructive apneas and hypopneas (a reduction in flow of 30% from the baseline) and mixed apneas; apnea index ($AI_{PSG}$), which included obstructive, mixed, and central apneas; and a hypopnea index ($HI_{PSG}$).

### CPAP device scoring criteria

Following the night of the CPAP PSG, the CPAP device was downloaded using ResScan (Ver 5.6.0.9419, ResMed). According to the device manufacturer,[13] an apnea is scored when there is a ≥75% reduction in the baseline root mean-square ventilation for ≥10 seconds. The ResMed VPAP ST-A with iVAPS (S9) does not differentiate the subtypes of apnea (obstructive vs central), and they are only reported by the CPAP device collectively as apneas. A hypopnea is scored when all of the following criteria are met: 50% reduction in the baseline root mean-square ventilation for ≥10 seconds; the hypopnea is not immediately followed by an apnea; and the event contains ≥1 partially obstructed breaths.

The CPAP download automatically generated the following respiratory indices, expressed as a count divided by the CPAP run time: apnea-hypopnea index ($AHI_{CPAP}$), which includes all apneas and hypopneas scored; apnea index ($AI_{CPAP}$), which includes all apneas scored; and a hypopnea index ($HI_{CPAP}$), which includes all hypopneas scored.

### Statistical analysis

Data were analyzed using Stata 10.0 (Stata Corporation, Irvine, CA). The PSG indices were compared with those calculated by the CPAP device algorithm. As device indices applying pediatric definition rules are not available, the respiratory indices provided by the device were compared with PSG indices to highlight the differences between these machine-generated indices and the clinical indices used by pediatric sleep services despite the differences between the definitions. As all data were skewed, results are presented descriptively using median (range) and compared using the Wilcoxon matched-pairs signed-rank test. The respiratory indices derived from the PSG were also compared with those automatically generated by the CPAP device/software using Bland-Altman plots, and a relationship between increasing mean and difference between the PSG and CPAP indices was tested using regression. The predictive value of CPAP indices for manually determined indices was summarized by reporting sensitivity, specificity, positive predicative value, and negative predicative values for a given residual OSA cutoff value for OAHI.

## RESULTS

A total of 58 CPAP PSGs were conducted during the study period. Twelve of these studies were excluded from analysis because different types of CPAP devices were used on the night of the PSG (most of these patients were using autotitrating CPAP at home and so were studied on that equipment on the night of their PSG). Of the remaining 46 PSGs included in the study, 17 (37%) were conducted as split diagnostic/CPAP study, and therefore only the CPAP treatment portion of the night was included in the analysis. The starting pressures ranged from 4 to 16 $cmH_2O$ as instructed by the referring physician. The

**Table 1**—Demographic and treatment details of recruited children (n = 46).

| Variable | Summary data |
|---|---|
| Age (yr) | 13.5 (4.6–20.0) |
| Sex, male [no. (%)] | 32 (70%) |
| BMI z-score | 1.3 (−1.3 to 2.8) |
| Weight (kg) | 58.8 (21.8–128.7) |
| Comorbidity | |
| None (%) | 11 (24%) |
| Downs (%) | 6 (13%) |
| Craniofacial syndrome/upper airway abnormality (%) | 9 (20%) |
| Obesity (%) | 4 (9%) |
| Ex-premature birth(%) | 4 (9%) |
| Adenotonsillectomy/other upper airway surgery (%) | 36 (78%) |
| Mask selection [full face (%)] | 24 (52%) |
| First CPAP titration study (%) | 20 (40%) |
| Duration of therapy | 1.6 yr (24 days–12.7 yr) |
| Device mode at home before study [APAP (%)] | 21 (46%) |
| Current pressure at home (fixed pressure devices only) | 9 $cmH_2O$ (5–16 $cmH_2O$) |
| Nights CPAP used[a] (%) | 87% (0–100%) |
| CPAP use (average hours:min on nights used) | 7:40 (0:02–10:43) |
| RDI (events/hr) | 1.5 (0.0–20.7) |
| OAHI (events/hr) | 0.2 (0.0–15.9) |
| CAHI (events/hr) | 0.3 (0.0–5.5) |
| Persistent OSA (OAHI ≥ 5/h [%]) | 4 (9%) |
| Starting CPAP pressure ($cmH_2O$) | 7 (4–16) |
| Physician determined optimal CPAP pressure ($cmH_2O$) | 9 (5–16) |
| Difference between optimal pressure and starting pressure ($cmH_2O$) | 1 (−1.0 to 9.0) |

Data are presented as median (range). [a]Nights CPAP used was calculated as a percentage of the 90 days before the PSG or for the entirety of CPAP acclimatization if the duration of treatment was <90 days. APAP = autotitrating CPAP, BMI = body mass index, CAHI = central apnea-hypopnea index, CPAP = continuous positive airway pressure, RDI = respiratory disturbance index, OAHI = obstructive apnea-hypopnea index.

median optimal pressure prescribed by the physician after analysis of the CPAP study was 9 $cmH_2O$ (range, 5–16 $cmH_2O$), with a median difference between the starting pressure and the optimal pressure of 1 $cmH_2O$ (range, −1.0 to 9.0 $cmH_2O$). On the night of the PSG, changes to pressure (by the staff conducting the manual titration) ranged from nil to an increase of 10 $cmH_2O$ from the starting pressure (median, 3 $cmH_2O$). Characteristics of the children on the night of their CPAP PSG are summarized in **Table 1**.

PSG and CPAP respiratory indices are presented in **Table 2** and compared in **Figure 1**. $AHI_{CPAP}$ was compared with both $RDI_{PSG}$ (all respiratory events including central apneas) and $OAHI_{PSG}$ because the latter is the variable used to define OSA in children and was not available from the CPAP device. There was no difference between the median $RDI_{PSG}$ and $AHI_{CPAP}$ ($P$ = .6). The $AI_{PSG}$ was significantly lower than $AI_{CPAP}$ ($P$ < .001), and the $HI_{PSG}$ was significantly higher than the $HI_{CPAP}$ ($P$ = .008). The $OAHI_{PSG}$ was significantly lower than the $AHI_{CPAP}$ ($P$ = .003).

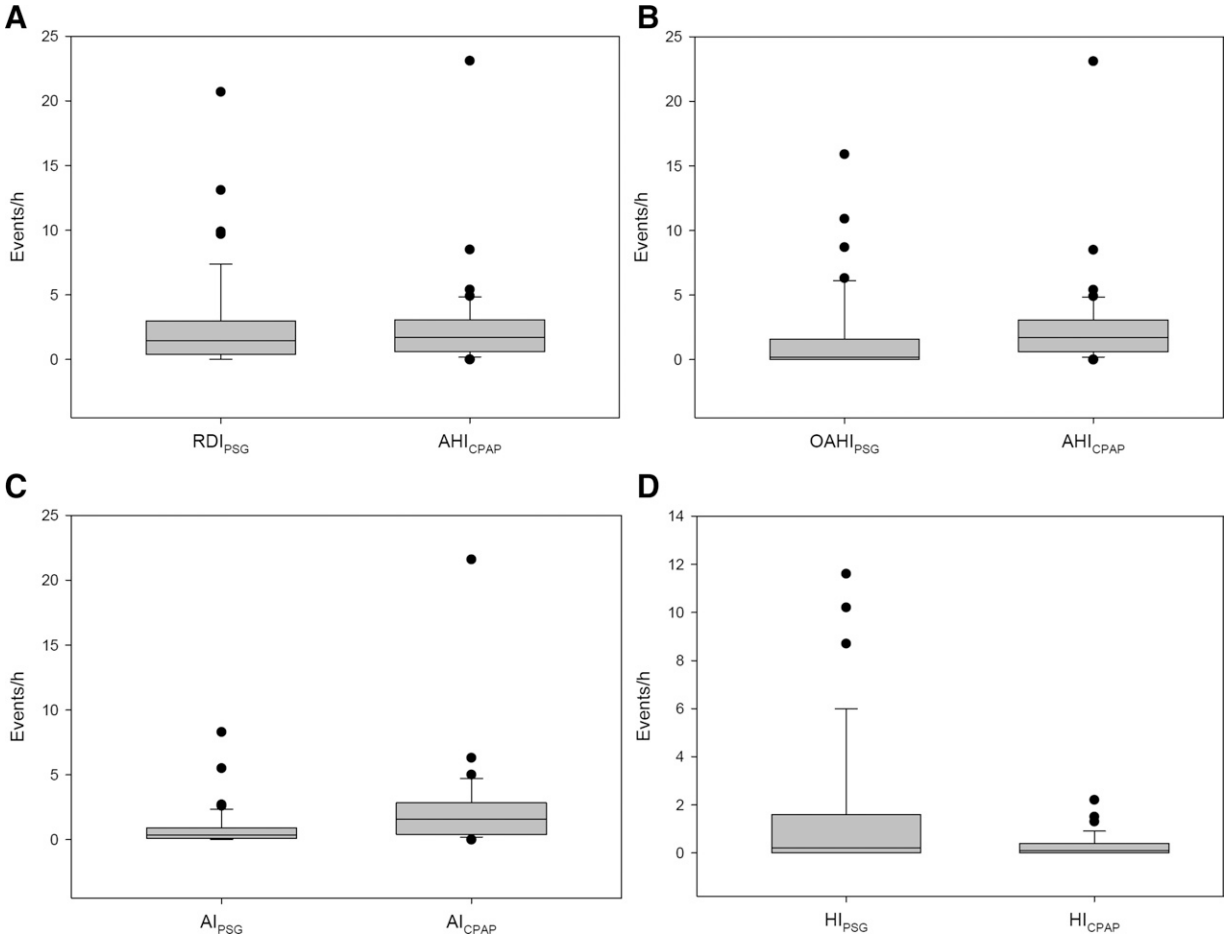
To determine whether key demographic or clinical variables affected the accuracy of the CPAP indices, we repeated the analyses by subgroup of children >12 and <12 years of age, those with or without craniofacial abnormalities, and children studied using nasal masks vs full face masks. For the age group analyses, the findings for $RDI_{PSG}$ vs $AHI_{CPAP}$ and comparing the apnea indices held in both age groups. The difference between $OAHI_{PSG}$ and $AHI_{CPAP}$ was only significant in the younger age group ($P$ = .02 compared with $P$ = .12 in the older group), and no significant difference in hypopnea indices was seen in either group. No significant difference was seen in the frequency of central apneas or obstructive hypopneas between the age groups as potential explanations for this finding. Similarly, differences were only present for the children without craniofacial abnormalities between $OAHI_{PSG}$ and $AHI_{CPAP}$ ($P$ = .002 compared with $P$ = .12 in the craniofacial group). The differences between apnea indices held for both groups, whereas the difference between $HI_{PSG}$ and $HI_{CPAP}$ was no longer significant between those with or without craniofacial abnormalities. Comparing children using nasal masks with those using full face masks, all results seen for the whole group were the same, except that neither mask group showed a significant difference in hypopnea indices.

**Table 2**—Respiratory indices for manually scored PSG and automatically derived from the CPAP.

| PSG Indices | | CPAP Indices | |
|---|---|---|---|
| $RDI_{PSG}$ | 1.5 events/hr (0.0–20.7) | $AHI_{CPAP}$ | 1.7 events/hr (0.0–23.1) |
| $OAHI_{PSG}$ | 0.2 events/hr (0.0–15.9) | | |
| $HI_{PSG}$ | 0.2 events/hr (0.0–11.6) | $HI_{CPAP}$ | 0.1 events/hr (0.0–2.2) |
| $AI_{PSG}$ | 0.4 events/hr (0.0–8.3) | $AI_{CPAP}$ | 1.6 events/hr (0.0–21.6) |

Data are presented as median (range). PSG = polysomnography, CPAP = continuous positive airway pressure, $RDI_{PSG}$ = respiratory disturbance index derived from polysomnography, $OAHI_{PSG}$ = obstructive apnea-hypopnea index derived from polysomnography, $HI_{PSG}$ = hypopnea index derived from polysomnography, $AI_{PSG}$ = apnea index derived from polysomnography, $AHI_{CPAP}$ = apnea-hypopnea index reported by continuous positive airway pressure device, $HI_{CPAP}$ = hypopnea index reported by continuous positive airway pressure device, $AI_{CPAP}$ = apnea index reported by continuous positive airway pressure device.

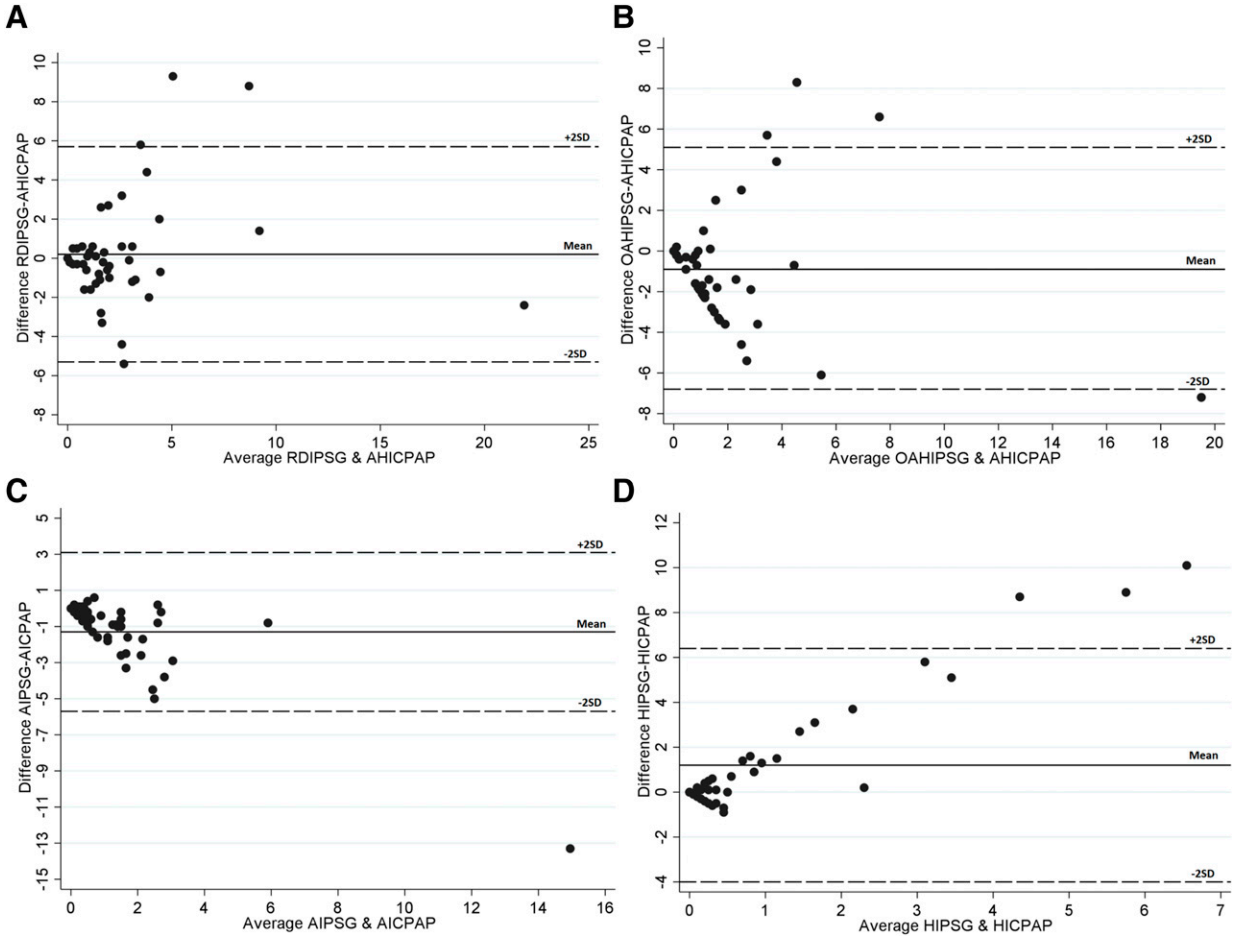
**Figure 1**—Comparison of PSG- and CPAP-derived indices.




Gray boxes indicate the median and interquartile range, whiskers indicate the 10th (below) and 90th (above) centiles, and the dots mark the position of all outliers. **(A)** $RDI_{PSG}$ compared with $AHI_{CPAP}$. **(B)** $OAHI_{PSG}$ compared with $AHI_{CPAP}$. **(C)** $AI_{PSG}$ compared with $AI_{CPAP}$. **(D)** $HI_{PSG}$ compared with $HI_{CPAP}$. PSG = polysomnography, CPAP = continuous positive airway pressure, $RDI_{PSG}$ = respiratory disturbance index derived from polysomnography, $OAHI_{PSG}$ = obstructive apnea-hypopnea index derived from polysomnography, $AHI_{CPAP}$ = apnea-hypopnea index reported by continuous positive airway pressure device, $AI_{PSG}$ = apnea index derived from polysomnography, $AI_{CPAP}$ = apnea index reported by continuous positive airway pressure device, $HI_{PSG}$ = hypopnea index derived from polysomnography, $HI_{CPAP}$ = hypopnea index reported by continuous positive airway pressure device.

The mean and difference between PSG- and CPAP-derived indices for each individual are presented in **Figure 2**. The mean (±2 standard deviation) difference between $RDI_{PSG}$ and $AHI_{CPAP}$ was 0.2 events/hr (−5.3, 5.7), with no significant relationship between the mean difference and the magnitude of the indices ($r^2$ = .02, $P$ = .37). Comparison of the $OAHI_{PSG}$ against the $AHI_{CPAP}$ also demonstrated a low mean difference of −0.9 events/hr (−6.8, 5.1) and no relationship with the magnitude of the indices ($r^2$ = .02, $P$ = .37). The mean difference between the apnea indices ($AI_{PSG}$ and $AI_{CPAP}$) was −1.3 events/hr (−5.7, 3.1), with the CPAP machine overestimating the number of apneas at higher apnea indices ($r^2$ = .72 for the relationship

**Figure 2**—Bland-Altman plots demonstrating the difference between the respiratory indices (PSG vs CPAP) and the change in difference with increasing indices.




**(A)** $RDI_{PSG}$ compared with $AHI_{CPAP}$. **(B)** $OAHI_{PSG}$ compared with $AHI_{CPAP}$. **(C)** $AI_{PSG}$ compared with $AI_{CPAP}$. **(D)** $HI_{PSG}$ compared with $HI_{CPAP}$. Mean difference is indicated by a solid horizontal line, and 2 SD above and below the mean difference (+2 SD and −2 SD, respectively) are indicated by dashed lines. PSG = polysomnography, CPAP = continuous positive airway pressure, $RDI_{PSG}$ = respiratory disturbance index derived from polysomnography, $AHI_{CPAP}$ = apnea-hypopnea index reported by continuous positive airway pressure device, $OAHI_{PSG}$ = obstructive apnea-hypopnea index derived from polysomnography, $AI_{PSG}$ = apnea index derived from polysomnography, $AI_{CPAP}$ = apnea index reported by continuous positive airway pressure device, $HI_{PSG}$ = hypopnea index derived from polysomnography, $HI_{CPAP}$ = hypopnea index reported by continuous positive airway pressure device, SD = standard deviation.

between the mean and the difference between the indices, $P < .001$; **Figure 2C**). The relationship was still significant if the outlier was removed ($r^2 = .23$, $P < .001$). The mean difference between the hypopnea indices ($HI_{PSG}$ and $HI_{CPAP}$) was 1.2 events/hr (−4.0, 6.4). In contrast to the apnea indices, the CPAP significantly underestimated the number of hypopneas at higher indices ($r^2 = .92$, $P < .001$; **Figure 2D**).

Using a manually scored $OAHI_{PSG}$ of ≥5 events/hr to denote the presence of significant residual OSA, the $AHI_{CPAP}$ correctly detected 39 of 41 children without residual OSA (specificity, 0.95), but only identified 1 of 5 children with residual OSA (sensitivity, 0.20; **Table 3**). In other words, the number of false-negative results was low (4 of 43 tests with an $AHI_{CPAP} < 5$ events/hr; negative predictive value, 0.91), but the number of false positives was high (2 of 3 positive results; positive predictive value, 0.33). Lower thresholds for a positive $OAHI_{PSG}$ resulted in very poor sensitivity and specificity. For example, using the internationally used threshold for the presence of OSA ($OAHI_{PSG}$ 1 event/hr), the sensitivity was 64% and specificity was 41%, with neither being high enough to be clinically useful.

## DISCUSSION

Although most children with OSA are successfully treated with adenotonsillectomy, an increasing number need treatment with CPAP.[1] The American Thoracic Society has cautiously advised that, in adults, CPAP-derived AHIs may be clinically useful at the ends of the spectrum (very high or very low values for residual events) but that providers should understand the definitions used in these algorithms and that the value of intermediate levels of residual AHI is unclear.[14] We designed this study to determine whether automatically generated respiratory indices from the ResMed VPAP ST-A with iVAPS (S9) could

**Table 3**—Using $AHI_{CPAP}$ to detect the presence of significant residual OSA ($OAHI_{PSG}$ ≥ 5 events/hr).

| | $OAHI_{PSG}$ ≥ 5 events/hr (Positive) | $OAHI_{PSG}$ < 5 events/hr (Negative) | Total |
|---|---|---|---|
| $AHI_{CPAP}$ ≥ 5 events/hr (Positive) | 1 | 2 | 3 |
| $AHI_{CPAP}$ < 5 events/hr (Negative) | 4 | 39 | 43 |
| Total | 5 | 41 | 46 |

$AHI_{CPAP}$ = apnea-hypopnea index reported by continuous positive airway pressure device, $OAHI_{PSG}$ = obstructive apnea-hypopnea index derived from polysomnography.

be used to monitor the effectiveness of treatment in children. We found only small mean differences between the $RDI_{PSG}$ and $AHI_{CPAP}$ and between the $OAHI_{PSG}$ and $AHI_{CPAP}$, but there was a relatively wide spread (about ±5 events/hr). The CPAP machine overestimated apneas, likely because of the different flow reduction criteria it uses to classify an apnea in comparison with American Academy of Sleep Medicine criteria (75%, rather than 90% reduction in flow[11]); counting central apneas; and scoring central events without the subsequent arousal or desaturation required by the American Academy of Sleep Medicine criteria.[11] This overestimation of apneas, especially at higher AHIs, is likely to be the explanation for an overestimation of the $AHI_{CPAP}$ compared with the $OAHI_{PSG}$ but not compared with the total $RDI_{PSG}$ (including central apneas) in our group. The difference in $OAHI_{PSG}$ and $AHI_{CPAP}$ was particularly evident in younger children and those without craniofacial abnormalities when studied as subgroups, although the small numbers in each group make these results less robust.

In contrast, the CPAP device studied underestimated hypopneas particularly at higher $OAHI_{PSG}$, which may have been attributable to the differences in the duration criteria between the 2 methods (10 seconds for the CPAP vs 2 respiratory cycles on PSG) or that the machine is scoring hypopneas as obstructive apneas because of the lower threshold for flow reduction required by the device to define an apnea. Given that most obstructive events in children are hypopneas, underestimation of these types of events in some children is the likely explanation for failure of the CPAP machine to detect significant residual OSA evident on PSG in several cases. Differences in hypopnea indices was no longer apparent when the cohort was subgrouped by age < 12 years, craniofacial abnormality, or type of mask used. The wide variability in hypopnea indices and small numbers in the subgroups are the likely explanations for this finding.

Previous studies in adults comparing the CPAP-derived respiratory indices with those simultaneously scored on a night of in-laboratory PSG have reported variable results, possibly attributable to the different CPAP devices studied. Most show good correlation between the two,[2–4] but others found $AHI_{CPAP}$ either overestimated $AHI_{PSG}$[5,6] or underestimated it, particularly when the latest American Academy of Sleep Medicine scoring rules were applied.[7] In general, differences were greater at higher AHIs, with events being underestimated at high AHI levels.[5,7,8] This is consistent with our results of a widening difference between the 2 methods at higher AHI values. It explains our finding of a strong specificity and negative predictive value for the presence of residual OSA but a poor sensitivity and positive predictive value, echoing the findings of 1 study in adults.[8]

In terms of individual event types, most studies have shown that CPAP devices tend to overestimate apneas and underestimate hypopneas[2,7,13,15,16] as was evident in our study. One study in adults pointed out that higher numbers of central apneas on the diagnostic study predicted a higher residual AHI on CPAP,[6] suggesting that central apneas are the major contributor to a device-reported residual AHI. This is of additional importance in children, where central apneas up to 5 events/hr do not reflect pathology[17] and should not therefore be considered in the assessment of residual OSA. Thus, both the tendency of the CPAP device to underestimate hypopneas (when these are the most common event type in children) and to count central apneas in the apnea index and AHI that are usually not of clinical relevance make the device AHI difficult to interpret, especially if it is high.

Our findings are also consistent with the only prior pediatric study investigating CPAP-derived respiratory indices with those manually scored.[9] In that study of 15 children on stable long-term CPAP therapy, the indices derived automatically from ResMed CPAP devices were compared with those manually determined on a night of in-laboratory polygraphy (using actigraphy to approximate sleep time without the use of electroencephalograms). That study also found that the $AHI_{CPAP}$ was significantly higher than manually scored AHI, mainly because of the CPAP machine scoring central apneas.

Our study is the first to compare respiratory indices reported by a CPAP device with traditionally manually scored events on PSG in children. Like all previous studies, generalizability of our results is limited by the fact that CPAP devices apply different algorithms, and thus our results for the ResMed VPAP ST-A with iVAPS (S9) may not be applicable to the use of other devices. The ability to separate central and obstructive apneas particularly may facilitate more accurate indices derived from a CPAP device when used in children. We also chose to compare residual respiratory events during a night of manual CPAP titration in children already established on CPAP, resulting in low indices for most children included. We would argue, however, that this would be the typical situation once a treatment pressure has been established for a given child, making our findings applicable to follow-up of children established on fixed-pressure CPAP. For example, a child who has responded well symptomatically to CPAP and has a low $AHI_{CPAP}$ may not require repeated in-laboratory PSG in a resource-limited setting.

In summary, automatically generated respiratory indices from the ResMed VPAP ST-A with iVAPS (S9) should be used with caution in children because of problems with overestimating apneas and underestimating hypopneas compared with PSG. These indices should not be used to rule out the presence of residual OSA in children that remain symptomatic on CPAP. A low $AHI_{CPAP}$ is reassuring in the context of a stable

patient but may miss ongoing hypopneas. CPAP providers should understand the performance of the algorithms used in individual CPAP machines in children specifically, and their applicability to clinical decision making.

## ABBREVIATIONS

AHI, apnea-hypopnea index
$AHI_{CPAP}$, apnea-hypopnea index reported by continuous positive airway pressure device
$AI_{CPAP}$, apnea index reported by continuous positive airway pressure device
$AI_{PSG}$, apnea index derived from polysomnography
CPAP, continuous positive airway pressure
$HI_{CPAP}$, hypopnea index reported by continuous positive airway pressure device
$HI_{PSG}$, hypopnea index derived from polysomnography
$OAHI_{PSG}$, obstructive apnea-hypopnea index derived from polysomnography
OSA, obstructive sleep apnea
PSG, polysomnography
$RDI_{PSG}$, respiratory disturbance index derived from polysomnography
RIP, respiratory inductance plethysmography

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## DISCLOSURE STATEMENT

All authors have seen and approved the final manuscript. Work for this study was performed at the Melbourne Children's Sleep Centre, Monash Children's Hospital, Melbourne, Australia. The authors report no conflicts of interest.