OBJECTIVES: It remains uncertain whether treatment with adenotonsillectomy for obstructive sleep apnea in children improves cognitive function. The Preschool Obstructive Sleep Apnea Tonsillectomy and Adenoidectomy study was a prospective randomized controlled study in which researchers evaluated outcomes 12 months after adenotonsillectomy compared with no surgery in preschool children symptomatic for obstructive sleep apnea.

METHODS: A total of 190 children (age 3–5 years) were randomly assigned to early adenotonsillectomy (within 2 months) or to routine wait lists (12-month wait, no adenotonsillectomy [NoAT]). Baseline and 12-month assessments included cognitive and behavioral testing, medical assessment, polysomnography, and audiology. The primary outcome was global IQ at 12-month follow-up, measured by the Woodcock Johnson III Brief Intellectual Ability (BIA). Questionnaires included the Pediatric Sleep Questionnaire, Parent Rating Scale of the Behavioral Assessment System for Children II, and Behavior Rating Inventory of Executive Function, Preschool Version.

RESULTS: A total of 141 children (75.8%) attended baseline and 12-month assessments, and BIA was obtained at baseline and 12-month follow-up for 61 and 60 participants in the adenotonsillectomy versus NoAT groups, respectively. No cognitive gain was found after adenotonsillectomy compared with NoAT, adjusted for baseline; BIA scores at 12-month follow-up were as follows: adenotonsillectomy, 465.46 (17.9) versus NoAT, 463.12 (16.6) (mean [SD]). Improvements were seen for polysomnogram arousals and apnea indices and for parent reports of symptoms (Pediatric Sleep Questionnaire), behavior (Behavior Assessment System for Children behavioral symptoms, \( P = .04 \)), overall health, and daytime napping.

CONCLUSIONS: Structured testing showed no treatment-attributable improvement in cognitive functioning of preschool children 12 months after adenotonsillectomy compared with NoAT. Improvements were seen after adenotonsillectomy in sleep and behavior by using polysomnogram monitoring and parental questionnaires.

WHAT’S KNOWN ON THIS SUBJECT: Studies to evaluate changes in neurocognition after adenotonsillectomy for obstructive sleep apnea suggest that younger children may have potential for greater improvement. The previous study with a randomized design was in school-aged children.

WHAT THIS STUDY ADDS: This randomized study of preschool children showed reduced frequency of day naps and confirmed polysomnographic and behavioral improvements after adenotonsillectomy compared with those still awaiting surgery, but our primary analysis showed no improvement in global IQ.

Most pediatric studies evaluating correlations between intellectual function and obstructive sleep apnea (OSA) have studied school-aged children. Deleterious impacts of snoring and OSA are reported on behavior and aspects of cognitive function in children, with emphasis on executive function regardless of OSA severity. The first line of treatment of childhood OSA is adenotonsillectomy. There is general agreement that children’s behavior improves after treatment with adenotonsillectomy, but impacts of treatment on intellectual function are less clear.

In a meta-analysis of cross-sectional studies, researchers concluded that attention-executive function and verbal ability improve after adenotonsillectomy compared with children’s own baseline and that attention-executive function and memory are restored. In 2 studies in preschool children, researchers found IQ values initially below the normal mean of 100 and reported increases at follow-up (90.2 ± 9.4 increased to 102.2 ± 7.2 [P < .001] and 82.5 ± 14.0 increased to 87.2 ± 14.7 [P = .02]), respectively. Song et al conclude that preschool children may show more recovery than school-aged children, requiring more studies in this age group.

One previous randomized study of adenotonsillectomy, undertaken in school-aged (age 5–9 years) children, was the Childhood Adenotonsillectomy Trial (CHAT) study. In the primary analysis, investigators found no change in measures of attention or executive function at 7-month follow-up after adenotonsillectomy, compared with controls who had not undergone surgery. Further analysis, modified from the original protocol, suggested small but positive effects of tonsillectomy on tests of nonverbal reasoning, attention, and fine motor skills that correlated to both respiratory disturbances and sleep quality. Effects on younger children remain uncertain because this, the most comprehensive study to date, targeted school-aged children. Given that children of younger age are in critical periods for brain development, and neural pathways for executive function are established by middle childhood, it was important to evaluate this question in younger children.

The current randomized study (the Preschool Obstructive Sleep Apnea Tonsillectomy and Adenoidectomy [POSTA] study) was undertaken in preschool children (3–5 years old) with the goal of evaluating whether adenotonsillectomy improved intellectual function after (early) adenotonsillectomy in this younger age group. We compared outcomes to children still waiting for surgery at the time of their 12-month follow-up (no adenotonsillectomy [NoAT]). Our hypothesis was that a cohort of children, younger than in previous studies and with a longer recovery time of 12 months, would show improved cognition after adenotonsillectomy compared with controls who were still awaiting surgery (NoAT).

METHODS

Design and Setting

This multicenter, randomized controlled study was undertaken at 3 Australian tertiary children’s hospitals. The protocol has been previously published. The trial was registered with the Australian and New Zealand Clinical Trials Registry (registration number ACTRN12611000021976).

Centralized ethical approval was obtained from the human research ethics committee at The Children’s Hospital at Westmead (CHW) and at each site (ethics approval number HREC/14/SCHN/332). Written informed consent was obtained from the parent or caregiver of the participating children. Regular teleconferences and/or face-to-face meetings were held among the investigators to discuss problems and ensure adherence to the protocol. The study was funded by government and philanthropic agencies with no commercial support. All authors are responsible for the completeness and accuracy of the data.

Eligibility and Randomization

Children were eligible if they were 3 to 5 years of age, without major medical comorbidities, and referred with symptoms of OSA to either the ear, nose, and throat (ENT) or sleep medicine services at participating hospitals.

The Pediatric Sleep Questionnaire (PSQ) was used to screen for symptoms of OSA, and a positive PSQ score (≥30% of positive answers) led to further evaluation. The secondary inclusion criterion was an obstructive apnea hypopnea index (OAI) value of ≥10 per hour, so children with primary snoring and with mild or moderate OSA were included. Eligibility required ENT evaluation as suitable for adenotonsillectomy, normal audiometry, and ability to undertake neurocognitive testing in English. Baseline evaluations included review by a pediatric sleep physician and an ENT surgeon, overnight polysomnography, neurocognitive testing by a psychologist, and questionnaires completed by the parents to assess the child’s executive function and behavior. After completing baseline evaluations, children were randomly assigned to adenotonsillectomy or NoAT groups. Because fewer children were likely to have higher apnea hypopnea index (AHI) values, we used block randomization for AHI values <5 or ≥5 obstructive respiratory events per hour to ensure that those with higher OAI values were evenly distributed between the adenotonsillectomy and NoAT groups. Randomization was centralized. As children were recruited, investigators telephoned an administrative assistant at CHW (who was otherwise uninvolved in the project) to receive randomly generated assignments using.
a randomization sequence provided by a statistician. When the study began, nonurgent surgical wait lists for children with mild to moderate OSA averaged 12 months or more at all participating hospitals so that surgery after a 12-month follow-up visit was considered routine care. For those randomly assigned to adenotonsillectomy in this study, surgery was within 2 months. Children with an AHI score of $>10$ events per hour were excluded and managed via clinical pathways for severe OSA, including adenotonsillectomy. Other exclusions included inability to perform the neurocognitive testing in English and an abnormal hearing test result (bilateral hearing loss $>35$ dB). Children in the routine waiting group did not receive any medical treatment during the period while they were waiting for surgery.

**Assessments**

Children underwent standardized polysomnography, medical review, audiology, and cognitive and behavioral assessments at baseline and at 12-month follow-up. Cognitive and behavioral testing was administered and scored by qualified and experienced psychologists under standard test conditions. Testing was completed in 1 session at a time of convenience to the parents or caregiver. The psychologist performing the testing was blinded to the random assignment of the subject, and parents were coached to avoid disclosure. Scoring was undertaken electronically. Additional details are in the Supplemental Information.

**Outcome Measures**

**Neuropsychological Testing**

The Woodcock Johnson III (WJ-III) Test of Cognitive abilities was used. It is used to measure cognitive function in individuals from age 2 years to adulthood. The Brief Intellectual Ability (BIA) score combines comprehension knowledge (verbal ability), fluid reasoning (thinking ability), and processing speed (efficiency in performing cognitive tasks) in a short but reliable measure of intelligence. The BIA score correlates well with the General Intellectual Ability (GIA) and other measures of intellectual ability. Many younger children could not complete all the tests required to generate a GIA score, so the BIA score, obtained in a greater proportion of the participants, was used as the primary outcome measure. The GIA reflects the best weighted combination of tests that account for the largest portion of the variance in a collection of tests and does not vary much with age. The GIA is a composite of oral vocabulary, number series, verbal attention, letter pattern matching, phonological processing, story recall, and visualization.

The Australian Adaptation Normative WJ-III software program was used to generate test and functional values (WJ-III Normative Update Compuscore and Profiles Program; Riverside; Houghton, Mifflin and Harcourt). The mean (SD) percentiles, $z$ scores, and $W$ scores (task proficiency) are reported.

**Questionnaires of Behavior and Executive Function**

*Behavior Assessment System for Children Parent Rating Scale, Behavior Rating Inventory of Executive Function, and Behavior Rating Inventory of Executive Function, Preschool Version*

Age-appropriate questionnaires of executive function, parental stress, and behavior were undertaken at baseline and 12-month assessments. The behavior was measured with high inconsistency scores. For the analysis, after excluding tests with high inconsistency scores.

**Polysomnography**

Full overnight sleep studies (polysomnography) were performed in clinical pediatric sleep laboratories. Sleep staging used 4 EEG leads (both left and right central and occipital leads), bilateral electro-oculographic leads (which also provide EEG signals), and submental electromyogram. To evaluate respiratory events, we used chest wall and abdominal movement measured with inductance plethysmography, surface measures of diaphragmatic and abdominal electromyogram activity, and airflow by using a pressure transducer signal from the nose via nasal prongs and from the mouth via thermistor. Oxyhemoglobin saturation was measured by pulse oximetry, and carbon dioxide levels were measured by using transcutaneous $\text{CO}_2$ Cardiac rhythm was monitored with standard electrocardiogram leads.

Studies were analyzed using the American Academy of Sleep Medicine 2007 guidelines with the Australasian Sleep Association amendment because those rules were current when the study protocol was established.$^{15,16}$ Obstructive apnea was defined as a cessation of airflow for at least 2 respiratory cycles. Hypopnea was defined as a reduction in airflow, resulting in either an arousal or desaturation of at least 3%. Central apnea was defined as cessation of airflow and respiratory effort for at least 20 seconds or $<20$
second duration but associated with an arousal or oxyhemoglobin desaturation of at least 3%. Total sleep time was determined, and apnea indices were calculated as the average number of apneic episodes per hour of sleep. The AHI is the average number of apneic and hypopneic episodes per hour of sleep, regardless of type. The OAHI is the number of obstructive and mixed apneas and hypopneas per hour of sleep. At each center, polysomnography analysis was limited to a maximum of 2 analysts with suitable concordance, blinded to the randomization of the subjects.

Other Outcomes

Caregivers were contacted at 2-month intervals after randomization. A set of 7 standard questions were provided to research assistants to ask during those phone calls (Supplemental Table 4).

Intervention: Adenotonsillectomy

Complete extracapsular tonsillectomy and adenoidecctomy was undertaken. Adenoidecctomy was undertaken regardless of the size of the adenoids, with diathermy an acceptable technique. The adenoidal bed was visualized at the end of the procedure to ensure that removal was satisfactory.

Adverse events are listed in the Supplemental Information.

Statistical Analysis

Every attempt was made to collect outcome data on all participants. Primary analysis was by intention to treat and used linear regression (analysis of covariance) in which WJ-III outcomes of BIA W score at 12-month follow-up were the dependent variables, with treatment group allocation (adenotonsillectomy or NoAT) the main effect variable and baseline scores the covariate. The use of regression allowed us to assess whether regression to the mean occurred and thus whether some children might benefit most, in addition to measuring the group effect. (See the Supplemental Information.)

RESULTS

Sample Characteristics

Study flow is shown in Fig 1. Including a feasibility study at CHW (Sydney) from January 2010 to December 2012, all study centers participated from January 2014 to 2017. We enrolled and randomly assigned 190 children and compared children who completed the study against those who showed no demographic differences.

After 12 months, 141 (75.8%) children attended follow-up visits, 136 (70.4%) completed the WJ-III testing, and BIA results were analyzed for 121 (64.4%). Results excluded from analysis included IQ subscales that children could not complete and BASC or BRIEF results with (in)consistency scores indicating unreliable responses. Baseline demographic and clinical characteristics were generally well balanced between the study groups as shown in Tables 1 and 2 and Supplemental Table 5.

Primary Outcome

At the 12-month follow-up, WJ-II results were available for 67 and 69 children in the adenotonsillectomy and NoAT surgical groups, respectively, with BIA scores available for 60 (adenotonsillectomy) versus 61 (NoAT) at both baseline and 12 months. Intellectual ability scores improved in both groups over time with no effect attributable to the intervention (adenotonsillectomy): baseline W scores for BIA = 448.36 (17.9) vs 451.3 (15.6) and 12 months = 465.46 (17.9) vs 463.12 (16.6) (adenotonsillectomy versus NoAT, respectively; not significant) (Fig 2). Valid GIA scores were available for 38 and 31 children in the adenotonsillectomy and NoAT groups, respectively, again with no effect attributable to the intervention (adenotonsillectomy): baseline mean (SD) W scores for these 2 measures are shown in Table 2. Among the subscales, significant improvement
was seen in long-term retrieval (mean difference: 4.06, \(P = .008\)) whereas the mean difference for visual-spatial thinking was 4.44 (\(P = .09\)).

**Secondary Outcomes**

The BRIEF questionnaire, used to assess executive function in everyday activities, was valid in 52 and 47 of the adenotonsillectomy and NoAT groups, respectively. T scores (mean: 50) showed variable shifts from baseline, but no effect was attributable to the intervention (adenotonsillectomy). Selected subscales are presented in Table 2, with full results presented in the Supplemental Information.

Routine parent questions also revealed that children in the adenotonsillectomy group had immediate and sustained improvements in sleep and “eating well,” with fewer reports of trouble breathing during sleep, snoring, and daytime sleeping. See Fig 3 and Table 3.

### Table 1: Baseline Demographics and Assessments

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Adenotonsillectomy</th>
<th>NoAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mo</td>
<td>46.5 ± 8.8</td>
<td>47.8 ± 8.8</td>
</tr>
<tr>
<td>Sex, male:female</td>
<td>52:47</td>
<td>57:34</td>
</tr>
<tr>
<td>Social risk score</td>
<td>2.47 ± 2.3</td>
<td>1.97 ± 1.9</td>
</tr>
<tr>
<td>PSQ score</td>
<td>0.62 ± 0.15</td>
<td>0.60 ± 0.16</td>
</tr>
<tr>
<td>W score ((n))a</td>
<td>448.4 ± 17.9 (89)</td>
<td>451.3 ± 15.6 (84)</td>
</tr>
<tr>
<td>BIA</td>
<td>452.8 ± 14.3 (66)</td>
<td>455.0 ± 13.7 (63)</td>
</tr>
<tr>
<td>Tonsil size, range 1–4</td>
<td>2.96 ± 0.53</td>
<td>2.98 ± 0.61</td>
</tr>
<tr>
<td>OAH</td>
<td>1.9 ± 1.9</td>
<td>1.9 ± 2.0</td>
</tr>
<tr>
<td>MinSaO2</td>
<td>88.5 ± 6.7</td>
<td>90.2 ± 3.9</td>
</tr>
</tbody>
</table>

Details of the social risk score are provided in the Supplemental Information. MinSaO2, minimum oxygen saturation value.

a For GIA and BIA, numbers in parentheses are numbers of children with valid scores.

### Table 2: Results of Primary and Secondary Outcome Parameters

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Adenotonsillectomy</th>
<th>NoAT</th>
<th>Adjusted Mean Difference</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WJ-III (W score)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIA</td>
<td>448.6 (17.0)</td>
<td>465.4 (17.8)</td>
<td>2.25</td>
<td>.29</td>
</tr>
<tr>
<td>GIA</td>
<td>453.2 (14.5)</td>
<td>472.4 (13.9)</td>
<td>2.35</td>
<td>.40</td>
</tr>
<tr>
<td><strong>Secondary</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WJ-III (W score)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GIA</td>
<td>56.1 (11.0)</td>
<td>52.9 (11.1)</td>
<td>-3.54</td>
<td>.78</td>
</tr>
<tr>
<td>BRIEF (T score)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Executive</td>
<td>56.1 (10.6)</td>
<td>53.8 (10.0)</td>
<td>-1.86</td>
<td>.33</td>
</tr>
<tr>
<td>Inhibition</td>
<td>56.8 (10.5)</td>
<td>53.8 (10.3)</td>
<td>-1.14</td>
<td>.28</td>
</tr>
<tr>
<td>Working memory</td>
<td>50.6 (10.3)</td>
<td>52.0 (9.2)</td>
<td>-2.20</td>
<td>.34</td>
</tr>
<tr>
<td>BASC (T score)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Behavioral</td>
<td>56.6 (10.3)</td>
<td>51.0 (11.6)</td>
<td>-3.56</td>
<td>.03</td>
</tr>
<tr>
<td>Adaptability</td>
<td>48.7 (10.2)</td>
<td>51.8 (11.1)</td>
<td>3.69</td>
<td>.06</td>
</tr>
<tr>
<td>Somatization</td>
<td>60.4 (8.4)</td>
<td>51.0 (9.9)</td>
<td>-1.37</td>
<td>.0003</td>
</tr>
<tr>
<td>Attention</td>
<td>55.2 (10.1)</td>
<td>49.9 (10.6)</td>
<td>3.69</td>
<td>.05</td>
</tr>
<tr>
<td>PSQ proportion “yes”</td>
<td>0.62 (0.15)</td>
<td>0.24 (0.18)</td>
<td>2.69</td>
<td>.07</td>
</tr>
<tr>
<td>Parent rating, out of 10</td>
<td>—</td>
<td>8.7 (1.2)</td>
<td>-0.21</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>Polysomnogram</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TST, min</td>
<td>469.2 (73.8)</td>
<td>481.8 (66.7)</td>
<td>-2.12</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Efficiency, %</td>
<td>84.9 (9.7)</td>
<td>87.1 (9.0)</td>
<td>2.57</td>
<td>.08</td>
</tr>
<tr>
<td>AHI, events per h</td>
<td>3.0 (2.1)</td>
<td>1.0 (0.8)</td>
<td>-1.11</td>
<td>.0001</td>
</tr>
<tr>
<td>OAH, events per h</td>
<td>1.9 (1.9)</td>
<td>0.3 (0.5)</td>
<td>-0.98</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Arousal, per h</td>
<td>11.0 (5.4)</td>
<td>9.1 (3.8)</td>
<td>-4.15</td>
<td>.001</td>
</tr>
<tr>
<td>MinSaO2, %</td>
<td>88.5 (6.7)</td>
<td>90.7 (4.0)</td>
<td>0.53</td>
<td>.27</td>
</tr>
<tr>
<td>MaxCO2, mm Hg</td>
<td>49.1 (5.3)</td>
<td>48.6 (5.5)</td>
<td>-0.40</td>
<td>.75</td>
</tr>
</tbody>
</table>

Measures are reported for baseline and the 12-mo follow-up. Measures included the following: WJ-III (W score); BIA; GIA; BRIEF T score (note, preschool and school-aged scores were combined); T score for the BASC; PSQ; parent rating, answer to the question, “On a scale of 1 to 10, how would you rate your child at the moment?”, total sleep time (TST) in minutes; sleep efficiency; total number of apneas and hypopneas per hour of sleep time; total number of obstructive and mixed apneas and hypopneas per hour of sleep time; minimum oxygen saturation value (MinSaO2); and maximum transcutaneous carbon dioxide (MaxCO2). —, not applicable.

a \(P\) values of significance.
DISCUSSION

In the primary analysis of this randomized study of adenotonsillectomy in preschool children symptomatic for OSA, it was found that although global IQ scores improved over time for both groups, no change in global IQ was attributable to the intervention (adenotonsillectomy). Questionnaire results demonstrated parent-perceived improvements in behavior and well-being; sleep changes were indicated by fewer day sleeps and improved polysomnography parameters. The study adds significantly to literature regarding this younger age group.

The expectation that IQ would improve after surgery was based on significant preceding literature: in a meta-analysis of 1697 children aged 5 to 17 years (mean = 9.81 years; SD = 0.34) from observational cohort studies, researchers compared children with OSA to controls and concluded that OSA is associated with reduced performance on neuropsychological measures. Severity of OSA (measured by OAH1) had no impact on the results of formal testing (generativity) or questionnaire-based evaluations (equivalent to our use of the BRIEF) for inhibition, working memory, and shifting. In a meta-analysis of 250 to 375 children aged 6.6 ± 2.3 years (range: 2.5–14 years) in prospective studies of adenotonsillectomy, researchers found 3 studies suggesting improvement in the preschool age group. The negative outcome of the CHAT study in school-age children left open the possibility of an age threshold effect. Our randomized design is helpful in answering the question, especially with a 12-month delay to follow-up. Although the trajectory of overall IQ change appeared improved in the adenotonsillectomy group, it was not clinically significant (Fig 2). Among subscales, long-term retrieval (memory) improved in the adenotonsillectomy group, and this is an area of neurocognition identified both as impaired and showing improvement after therapy in adult OSA. Possible explanations for improved neurocognition over time include improvements with age and/or effects of development and a learning effect, although the 12-month recommended retesting interval, included in our design, minimizes any learning effect. It may also be important that we excluded children with hearing loss from the baseline assessments, a factor not routinely considered in studies of OSA and IQ, despite its demonstrable association with executive function in OSA. Nonetheless, our primary analysis rejects the hypothesis that younger (preschool) children have improved global IQ after earlier intervention with adenotonsillectomy, nor were there improvements in BRIEF scores (parent-reported executive function).

Notwithstanding the bias in parent reports of symptoms, our questionnaire assessments of behavior and symptoms indicated large parent-perceived improvements after adenotonsillectomy and that those improvements were sustained over the 12-month follow-up. Importantly, we were able to compare against our control group in which changes were minimal. Broad questions highlighted the differences in overall symptoms of OSA, such as snoring and breathing difficulties (Table 3, Fig 2).

An interesting, and perhaps important, finding was that fewer preschool children continued day sleeps after adenotonsillectomy (Fig 2B). This is the first confirmatory report that preschool children stop day sleeps after adenotonsillectomy compared with a randomized (control) group. Although sleepiness is commonly reported in association with OSA, previous documentation of improvement after...
adenotonsillectomy is limited, undertaken in older children, and used the modified Epworth Sleepiness Scale, including the CHAT study and a study of children with narcolepsy and OSA. The only parameter on our polysomnographs, other than apnea indices, to show improvement in the group who underwent adenotonsillectomy was the arousal index, in which differences were statistically, but not clinically, significant and remained in the normal range for our laboratory. This suggests that polysomnography parameters are relatively insensitive to the changes that occur or that the brain is sensitive to arousal (Table 2).

An important difference between the current and previous studies is our use of the PSQ reports of symptoms. The majority of children in this study had mild OSA (Supplemental Fig 4A), but this also meant we included chronically snoring children with negative polysomnography results (primary snorers). Although not all sequelae of OSA are apparent in children with an AHI value of <1.0 per hour, there is increasing evidence that measurement of snoring in children can identify different physiologic phenomena to the AHI and that this potentially associates more closely with sequelae than polysomnography measures.

Our analysis was for primary and secondary endpoints in a clinical trial in which treatment was randomized. Baseline value of the outcome variable was the only predictor used in the analysis, intended to give a more precise estimate of the treatment effect rather than because we believed there may be imbalance. More detailed analyses, such as those undertaken by Taylor et al with the CHAT data, would not be appropriate in this report.

Limitations of the study are common to randomized trials and our selected method of analysis. The most important are difficulties with recruitment and retention of subjects in a study that can be demanding of families with young children, creating an inherent loss of data across time. Although reliance on intention to treat gives more “real world” results, it can cause loss of power because of subject attrition. Together, these
factors combine to increase the risk for a type II error. The time from protocol development to completion of the study has been significant, and other literature has been published while the study was in progress, so more specific testing has potential to detect changes attributable to OSA.9

Long-term memory was a single IQ subscale showing statistically significant change (see Supplemental Table 6). Given the overall negative result and the number of analyses undertaken, it may be a chance finding, but larger studies including more children with moderate or severe disease and/or more detailed analysis, such as that undertaken by Taylor et al,9 may clarify this. When preparing the protocol, we used the standard IQ testing scores with a mean of 100 and SD of 15 points for our power calculations and aimed to detect a 0.5-SD change. When analyzing our results, it became clear that for children aged 3 to 5 years, the BIA score from the WJ-III was the most appropriate measure of IQ. Mean values for the W score vary with age (from 432.84, 445.86, and 458.32 at ages 3, 4, and 5, respectively), with SD values ranging from 8.99 to 12.28 (WJ-III technical manual), and this increase with age accounts, at least partly, for the increase seen in both adenotonsillectomy and NoAT groups. Study recruitment ended when we were close to our target (190 of 210) and could reasonably expect to complete the testing of all recruited children with available funding.12 The numbers in our follow-up of 64 per group give 80% power to detect a 0.5 SD, and our achieved sample size of 60 out of 61 for the BIA has 78% power to detect 0.5-SD difference in the BIA scores, which is further strengthened by our analysis method accounting for baseline values.26 Evidence suggests that IQ measures in preschool are stable, despite this still being a critical period of brain development, and for comparison of the effect size, differences of 0.5 SD or even smaller are considered significant across studies examining the effects of lead exposure on cognitive performance.27,28 It may be that the inclusion of mildly affected children diluted our results, although analysis by OAHI severity did not reveal such an effect. Problems contributing to all studies evaluating the influence of insults or interventions on IQ, especially in younger children and evident in literature pertaining to brain injury, include difficulties determining influences of ongoing development relative to those of the injury and then the impact of any intervention and interactions between those processes.29 Although surgery or anesthesia itself may have a detrimental effect on children’s cognition and contribute to our negative finding, more recent studies in this field have been reassuringly negative.30

**CONCLUSIONS**

In this study, we demonstrated improvements in polysomnography parameters, sleep quality, parent-reported symptoms, and aspects of behavior in preschool children with mild to moderate OSA undergoing early adenotonsillectomy compared with those awaiting surgery on routine waitlists. No difference in the global cognitive measures was attributable to study intervention at a 12-month follow-up.

**ACKNOWLEDGMENTS**

We thank the families of the participants in this study and The Australian Sleep Research Network for their support toward the protocol development. We also thank research staff Melissa Neylan, Sarbjeet Kaur, Anna Kontos, Sylvia Pignata, Chenda Castro, and Marie-Josee Leclerc; clinicians Drs Carolyn Dakin, Declan Kennedy, Daniel Novakovic, Joanna Walton, and Hannah Burns; and statisticians Drs Liz Barnes and Anne Bernard.

**ABBREVIATIONS**

AHI: apnea hypopnea index
BASC: Behavior Assessment System for Children
BASC 2: Behavior Assessment System for Children–II
BIA: Brief Intellectual Ability
BRIEF: Behavior Rating Inventory of Executive Function
BRIEF-P: Behavior Rating Inventory of Executive Function, Preschool Version
CHAT: Childhood Adenotonsillectomy Trial
CHW: The Children’s Hospital at Westmead
ENT: ear, nose, and throat
GIA: General Intellectual Ability
NoAT: no adenotonsillectomy
OAHI: obstructive apnea hypopnea index
OSA: obstructive sleep apnea
POSTA: Preschool Obstructive Sleep Apnea Tonsillectomy and Adenoidectomy
PRS: Parent Rating Scale
PSQ: Pediatric Sleep Questionnaire
WJ-III: Woodcock Johnson III

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**TABLE 3 Proportion of Parents Answering “Yes” to the Routine Follow-up Questions.**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Adenotonsillectomy</th>
<th>NoAT</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snoring, % yes</td>
<td>17.5</td>
<td>93.2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Trouble sleeping at night, % yes</td>
<td>8.4</td>
<td>74.1</td>
<td>&lt;.001a</td>
</tr>
<tr>
<td>Day sleeps, % yes</td>
<td>6.8</td>
<td>43.8</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Trouble breathing when asleep, % yes</td>
<td>11.5</td>
<td>44.2</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Eating well, % yes</td>
<td>88.9</td>
<td>59.4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Overall rating, out of 10</td>
<td>8.7</td>
<td>5.7</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Further details of the questions are provided in the Supplemental Information.

* Also changed with time.
For data sharing, the database will be maintained, permitting sharing of deidentiﬁed data. This trial has been registered with the Australian and New Zealand Clinical Trials Registry (https://www.anzctr.org.au; registration number ACTRN12611000021976). For data sharing, the database will be maintained, permitting sharing of deidentiﬁed data for 4 years after publication. Exported data will therefore be available to applicants whose submitted proposals are approved by a data-sharing committee.

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