Obstructive Sleep Apnea Syndrome Increases Pedestrian Injury Risk in Children

Kristin T. Avis, PhD, CBSM[1], Karen L. Gamble, PhD[2], and David C. Schwebel, PhD[3]

Objectives To evaluate pedestrian behavior, including reaction time, impulsivity, risk-taking, attention, and decision-making, in children with obstructive sleep apnea syndrome (OSAS) compared with healthy controls.

Study design Using a case control design, 8- to 16-year-olds (n = 60) with newly diagnosed and untreated OSAS engaged in a virtual reality pedestrian environment. Sixty-one healthy children matched using a yoke-control procedure by age, race, sex, and household income served as controls.

Results Children with OSAS were riskier pedestrians than healthy children of the same age, race, and sex. Children with OSAS waited less time to cross ($P < .01$). The groups did not differ in looking at oncoming traffic or taking longer to decide to cross.

Conclusions Results suggest OSAS may have significant consequences on children's daytime functioning in a critical domain of personal safety, pedestrian skills. Children with OSAS appeared to have greater impulsivity when crossing streets. Results highlight the need for heightened awareness of the consequences of untreated sleep disorders and identify a possible target for pediatric injury prevention. *(J Pediatr 2015;166:109-14)*.

Annually, 5300 American pedestrians are killed and 85 000 others are injured; over one-third of injured pedestrians are children.[1] In middle childhood, about 60% of pedestrian injuries and mortalities occur when the child is crossing a road at or between intersections, typically within one-half of a mile of the child's home.[2-4] Several studies suggest young children regularly negotiate dangerous street environments alone when going to and from school.[2,5-7] Not surprisingly, prevention of pediatric pedestrian injury has been targeted as a national public health priority.[8]

Many factors contribute to unintentional pedestrian injury. Among them are cognitive and temperamental traits of the pedestrian, including reaction time, impulsivity, risk-taking, attention, and decision-making.[9-12] These same characteristics that influence pedestrian safety are negatively influenced by sleepiness, both from sleep deprivation/insufficient sleep and from sleep disorders such as obstructive sleep apnea syndrome (OSAS).[13-18]

OSAS is a common sleep-related breathing disorder, with estimated prevalence of 1%-5% among nonobese children and 25%-40% in obese children.[19,20] Sleep disorders put adults at high risk for human error, mental inefficiency, and injury.[13,14] In adults, OSAS has negative consequences on mood and behavioral regulation and on neurocognitive functioning, including learning, vigilance, attention, memory, problem solving, and visual and motor functioning.[20,21] Adults with OSAS are more likely to have daytime sleepiness resulting in motor vehicle accidents and occupational injury.[14,15]

The effect of OSAS on child safety is less well understood. Emerging evidence suggests sleep disorders such as OSAS may cause significant daytime consequences in children performing basic laboratory tasks requiring cognitive skills such as impulse control, reaction time, memory, attention, decision-making, regulation of risk, and regulation of emotions,[16-18] but little research investigates how pediatric sleep disorders such as OSAS may influence children's safety in applied, real-life settings.

Pedestrian behavior is a highly complex cognitive and perceptual task. A safe pedestrian must simultaneously process several pieces of information, interpret their meaning, and make a decision to cross the street when a safe opportunity arises. These tasks must occur very quickly. Impulse control, attentional processes, memory, and reaction time are critical components of pedestrian safety.[9,12,22] Given cognitive impairments among children with OSAS reported in laboratory tasks,[16-18] children with OSAS may have significant deficits in pedestrian safety. This study examined that possibility. Using an interactive and semi-immersive virtual pedestrian environment, 60 children with OSAS and 61 yoke-matched healthy controls crossed a virtual street several times. We hypothesized children with OSAS would have a greater number of hits or close calls with virtual vehicles compared with healthy children. We further hypothesized that children with OSAS would look at traffic less before crossing, would wait

ADHD	Attention deficit/hyperactivity disorder
BMI	Body mass index
NPSG	Nocturnal polysomnography
OSAS	Obstructive sleep apnea syndrome
PDSS	Pediatric Daytime Sleepiness Scale
VRPE	Virtual reality pedestrian environment

From the Departments of [1]Pediatrics, [2]Psychiatry, and [3]Psychology, University of Alabama at Birmingham, Birmingham, AL

Supported by the *Eunice Kennedy Shriver* National Institute of Child Health & Human Development (R01HD058573) and the Faculty Development Office at the University of Alabama at Birmingham. The content is solely the responsibility of the authors and does not necessarily represent the official views of the *Eunice Kennedy Shriver* National Institute of Child Health & Human Development or the National Institutes of Health. The authors declare no conflicts of interest.

http://dx.doi.org/10.1016/j.jpeds.2014.09.032

less time before initiating a cross, would take longer to decide to cross, and would select unsafe traffic gaps more often than healthy control children.

Methods

One hundred twenty-one children participated; 61 of the children were diagnosed with OSAS. Diagnosis and recruitment of that portion of the sample occurred at the Pediatric Sleep Disorders Center at Children's of Alabama. All participating children met International Classification of Sleep Disorders Second Edition diagnostic criteria for OSAS[23] based on diagnostic assessments that included nocturnal polysomnography (NPSG) using Sandman 9.2 technology software (Embla, Broomfield, Colorado) and thorough clinical evaluation from 1 of 2 attending board-certified sleep specialists early in the morning after the overnight NPSG. Standard polysomnography consisted of electroencephalogram, electromyogram, electrooculogram (right, left), arterial oxygen saturation (SaO_2) oximeter pulse wave form, and end-tidal carbon dioxide tension, nasal pressure monitoring, oronasal flow using thermistor, and thoracic and abdominal wall motion. Standard pediatric scoring was used for respiratory events.[24] Diagnosis of OSAS was defined as apnea hypopnea index ≥1 per hour.[23]

Exclusion criteria included cognitive or physical disabilities that prevented full participation in the experimental protocol (eg, intellectual disability, blindness, use of a wheelchair); comorbid medical or neurologic conditions; or antipsychotic medication use. No children were excluded for these reasons. One child with OSAS requested withdrawal from the study without explanation and no usable data were available for that child. To verify sleepiness, we sampled level of sleepiness using the Pediatric Daytime Sleepiness Scale (PDSS).[25] Children with OSAS scored high on the scale (M = 17.23, SD = 7.38; mean in validation work 15.3).[25]

Sixty-one healthy children were recruited from the community using a laboratory database of community residents interested in participating in research. Recruitment occurred by searching the database for potential participants who matched children with OSAS by age, sex, race, and average income in the zip code of residence. This strategy, sometimes called yoke-matching, yielded a control sample with demographic characteristics that were quite similar to those in the case sample of children with OSAS. The same exclusion criteria used in the case sample were applied; no children were excluded. We also screened for diagnosed sleep disorder, and no parents reported their child had any. The control sample was adequately alert with a mean PDSS score of 12.03 (SD = 5.10).[25]

Children provided informed assent and caregivers informed consent. Caregivers prohibited caffeine intake for children the morning of the research appointment and were instructed to keep children awake after their routine wake time in either the Pediatric Sleep Disorders Center (children with OSAS) or during the drive to the appointment (healthy controls). Once the family arrived at the appointment and consent processes were completed, children participated in the virtual reality pedestrian environment (VRPE) while caregivers completed demographic questionnaires. The research session lasted approximately 1 hour, and families were compensated for their time. The study protocol was approved by the Institutional Review Board at the University of Alabama at Birmingham.

VRPE

Details of the VRPE, including validation data demonstrating behavior in the virtual world corresponds with behavior in real pedestrian environments among both children and adults are available elsewhere.[10] In that study, construct validity was demonstrated with significant correlations between behavior in the virtual and real worlds among both children and adults. Convergent validity was shown by correlations between parent-reported child temperament and behavior in the virtual world. Internal reliability of various measures of pedestrian safety in the virtual world was demonstrated. Face validity was demonstrated by users' self-reported perception of realism in the virtual world. Additional evidence of the environment's validity comes from several studies showing impaired pedestrian behavior under a variety of conditions and situations among both children and adults.[10,26-32] Taken together, we believe the VRPE offers a valid tool to study children's pedestrian injury risk without exposing children to actual traffic.[10,26-32]

While participating in the virtual environment task, children stood on a wooden simulated curb and viewed the virtual pedestrian environment on 3 consecutive monitors arranged in a semicircle in front of them. Children were immersed in the virtual environment as they watched vehicles pass bidirectionally on the screens and heard environmental and traffic noise through speakers in the room. After deciding it was safe to cross, they stepped off the curb onto a pressure plate connected to the computer and a gender-matched avatar was then activated to cross the street. The avatar's walking speed in the VRPE matched children's walking speed, which was evaluated prior to the VPRE task in a separate location. If the avatar safely reached the other side, children heard 1 of 2 positive messages such as "Yes! Great job!" If the child made it across safely but was close to being hit by a car, the child heard, "Whoa! That was close!" If the child was struck by one of the cars, they heard, "Uh oh, you should try that again." Thus, the child was immersed into a virtual world while deciding when it was safe to cross. After choosing to cross, the world became third-person, and the child witnessed the safety (or danger) of the crossing. During the experimental visit, children performed 10 practice trials to reduce learning effects and then engaged in 12 virtual street crossings. Behavior in the 12 crossings was used for analysis.

Measures of Crossing Behavior

We considered 5 pedestrian outcome measures. First, we looked at overall risk of pedestrian injury, based on the count of hits/close calls children experienced over the 12 simulated