Needham Board of Health

REVISED AGENDA

Thursday October 18, 2018
7:00 – 9:00 a.m.

Multi-Purpose Room
Rosemary Recreation Complex
178 Rosemary Street, Needham MA 02494

- **7:00 to 7:05 – Welcome & Review of Minutes (September 14th)**
- **7:05 to 7:40 – Staff Reports (September)**
- **7:40 to 7:45 – Project Update & Possible Regulation Discussion—Concussion Prevention and Public Education**
- **7:45 to 7:50 – Discussion about the Health Effects of Natural Gas**
- **7:50 to 8:00 – Discussion about Tobacco Regulation Edits for Workplace and Smoking Setback Distance**
- **8:00 to 8:35 – Discussion of Tobacco 21 and Flavor Restrictions with Dr. Lester Hartman and Professor Mark Gottlieb**
- **8:35 to 8:50 – Continued Review and Discussion: Goal Setting for FY 2019 and FY 2020**
- **8:50 to 8:55 – Continued Discussion of Electro-Magnetic Fields (EMF) and Health**
- **8:55 to 9:00 – Other Items**
- **Next Meeting (tentatively November 16th, 7:00 – 9:00 a.m.)**
- **Adjournment**

(Please note that all times are approximate)

178 Rosemary Street, Needham, MA 02494
E-mail: healthdepartment@needhamma.gov
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Web: www.needhamma.gov/health

Needham Board of Health Minutes

September 14, 2018

Board: Edward Cosgrove, PhD, Vice Chair
Stephen Epstein, MD, MPP, Chair
Kathleen Ward Brown, ScD, Member

Staff Present: Timothy Muir McDonald, Director; Tara Gurge, Assistant Director; Maryanne Dinell; Carol Read; Diane Acosta; Dawn Stiller; Catherine Delano; Tiffney Zike

Convene: Rosemary Recreation Complex, 178 Rosemary Street, Hillside Conference Room

Dr. Stephen Epstein, Chair of the Board of Health, called the meeting to order at 7:03 am

Minutes

Dr. Cosgrove made a motion to approve the July 20 meeting minutes. Dr. Brown seconded the motion. Upon motion duly made and seconded, the minutes of the July 20 meeting were approved. The motion was carried. The vote was unanimous.

Staff Reports

Traveling Meals Coordinator Report-- Ms. Maryanne Dinell

The summer meal delivery went smoothly. One incident of a client on the floor; 911 was called and the person survived. The numbers were down again in August; Ms. Dinell noted that for those who can afford it there are more meal delivery options catered to individual taste.

Substance Abuse Coordinator Report—Ms. Catherine Delano

Ms. Delano and the prevention team have been preparing for the 2018-2019 year with a focus on sustainability. Ms. Delano, Ms. Karen Shannon, and Ms. Carol Read attended the National Drug Prevention Week Network conference.

Ms. Delano noted that a second secure drug disposal unit is now available at Beth Israel Deaconess Hospital.

Implementation of the Youth Mental Health First Aid Grant with Youth and Family Services will begin in October. Ms. Delano is working with Ms. Katy Colthart to provide Youth Mental Health First Aid workshops to Needham community members.

Environmental Health Report--Ms. Tara Gurge
Ms. Diane Acosta contributing

Ms. Gurge reported that body work permits are complete.

Ms. Gurge covered several housing unit issues.

Ms. Gurge received an emergency call from a resident at Webster Green as the property no longer has a resident advocate under the new property management company. A resident's buzzer was not working along with several other issues so she has been working with Ms. Jessica Moss at Elder Services to resolve the issues. Final inspection will be next week.

A Needham Housing Authority resident who was not happy with the turnaround for work orders called Ms. Acosta directly to get the division involved in various violations, bypassing the Housing Authority work order system. The Director was made aware of the issue and the tenant is now working within the system.

Mr. McDonald noted that a major Health and Human Services goal remains advocating for more accessible and affordable housing, especially for the elderly. Dr. Cosgrove said that he has had several discussions with friends who would like to move to smaller housing in Needham but find it difficult to find something affordable if they sell a house in the $700,000.00-$800,000.00 range.

Swimming Pool Updates

1) Rosemary Pool was permitted for August 9th opening.

2) Modera pool on Greendale Ave. was permitted.

4) Homewood Suites pool inspections and log checks are going well and the Certified Pool Officer is now on site.

Mr. McDonald noted that since Homewood Suites and Residence were so willing to pay a daily fine rather than meeting the standard for opening their pools in July, he recommends requesting that Town Meeting revise the fine structure to make it in an incentive for pool operators to meet the opening standards. Dr. Cosgrove noted that at the Massachusetts Association of Health Board meeting on September 12, the issue was raised and he understood that the fine can be increased to $1500.00 per violation. It is unclear if, or how, the fines can be increased beyond $1500. Dr. Epstein recommended raising the fine before making a request to Town Meeting. Mr. McDonald will check whether the State regulations supersede the Town or vice versa.

Dr. Cosgrove asked Ms. Acosta about the Speedway gas station re-inspection. Ms. Acosta reported that there were two minor violations that were corrected when she returned. She noted that the heavy turnover at Speedway and other gas stations and convenience stores necessitates regular inspections.

Ms. Gurge mentioned that once the risk-based inspection schedule is adopted, Environmental Health will still inspect tobacco retail establishments every 6 months due to management changes.

Ms. Gurge reported that there is now a $125 charge for non-compliance re-inspections above and beyond the routine inspection and one follow-up. She remains fairly certain that Acapulco's will not be able to renew their lease because the dispute between restaurant and landlord remains ongoing. Dr. Brown asked about the lack of lights in Acapulco's parking lot and Ms. Gurge said that she will follow up to make sure they are replaced.

Public Health Nurse Report—Ms. Tiffney Zike

Ms. Zike reported an increase in pertussis cases during July. There was a big spike in Lyme disease in July and Massachusetts is expecting West Nile virus and Lyme disease to spike this fall. It was reported

that there was one communicable disease with a healthcare worker and a negative stool had been collected to return to work. There was a case of latent TB that was high risk. Ms. Zike noted that state law requires notification to Local Boards of Health with a latent TB case, but not an investigation. There was a discussion about looking into why it was labeled high risk. Ms. Zike reported that the October flu clinics are scheduled and advertised. The Health Division will pilot high dose flu vaccine for the first time.

Regional Substance Abuse Coordinator Report--Ms. Carol Read

Ms. Read presented the spring 2018 compliance check data on alcohol sales to minors as requested by the Board at its July 20 meeting. Compliance checks were conducted in all four towns of the SAPC region—Dedham, Needham, Norwood, and Westwood.

In Needham, there are Needham 29 total licensees and 28 of those were checked (22 restaurants and bars; 6 package stores). There were three violations for were for selling to minors in a bar or restaurant and one sale to a minor in a store.

Ms. Read reported that all four Chiefs of Police and Public Health Directors are strongly committed to twice yearly alcohol checks to prevent serving and retail sales to minors as well as over-pouring for adults. Ms. Delano noted that youth know which establishments are likely to sell alcohol to them. Social access to alcohol was also identified as a community risk factor coupled with community norms that are favorable to alcohol use. This led to a discussion about Needham's success in reducing underage access to tobacco through regular compliance checks and store inspections, enforcement of penalties for sales to minors, and tobacco licensee training. Ms. Read said that, based on the successes of youth tobacco prevention, the Substance Abuse Prevention Collaborative plan includes implementing similar strategies regarding youth access to alcohol.

Ms. Read reported that that Ms. Emily Sanders, a student at the BU School of Public Health, has conducted a PhotoVoice project with youth from all four towns. The project focused on teens' perceptions and experiences with alcohol, but touched on marijuana and e-cigarettes as well. Ms. Read said that some of the towns will invite the youth to present the PhotoVoice project. Dr. Cosgrove recommended that Needham youth should present the project to the Select Board. Ms. Read noted another scheduled TIPS licensee training program in November.

Ms. Read noted that the Substance Abuse Prevention Collaborative offers training for responsible beverage sales and servers. The next training will be on November 5.

Ms. Read helped coordinate a Drug Free Community Grant Writing training in Braintree for 24 people.

Ms. Read announced that the Dedham Public Health Department has received the Drug Free Communities grant which funds community coalition to work to prevent underage substance use.

Mr. Timothy Muir McDonald-Directors' Report

<u>Healthy Aging</u>

Mr. McDonald noted that the Accreditation and Healthy Aging-Safety at Home reports are in the Board packet. The Safety at Home project was implemented this September during the fall prevention week kickoff. The project includes an in-home assessment, referrals to the Matter of Balance classes at the

Center at the Heights and, when possible based on age and income, small grants for simple home modifications such as grab bars.

Mr. Stephen Jones, representing the Sierra Club participating via conference call

Mr. McDonald noted that the Board had agreed to have a 10 minute conference call with Mr. Stephen Jones representing the Sierra Club and its concerns about leaking natural gas pipes and inappropriate gas stove use such as using a stove as a heating source. Dr. Epstein noted that, with the explosions in the Lawrence-Andover area last night, the State may be forced to require utilities to repair gas leaks.

Mr. McDonald then called Dr. Jones. Dr. Jones said that he was concerned about 51 unrepaired gas leaks in Needham in 2017 and children's respiratory disease caused by cooking with gas indoors without a proper venting system.

Dr. Brown noted that home use is only a hazard if not properly installed and maintained and said that reports show gas stoves with proper ventilation have occupants with higher lung function.

Dr. Jones said that gas companies are required to report on other chemicals, such as benzene, in the gas lines, and that he has concerns about these other compounds. Dr. Epstein referred to the Environmental Protection Agency report which does not address cooking stoves but references instead furnaces and boilers. Dr. Epstein noted that trace elements, including benzene, are combusted completely if the boiler is maintained by the homeowner. A discussion ensued about combustion and the importance of distinguishing between data association versus data demonstrating causation.

Dr. Jones will send an article ("Gas is the Past") for the Board's review and, at Dr. Epstein's request, the Comprehensive Health Impact Report prepared by public health authorities

Ms. Gurge and Mr. McDonald will schedule a meeting with Dr. Jones later in the fall and will report to the Board after the meeting.

Following the phone call with Dr. Jones, Mr. McDonald mentioned the ongoing concern regarding the Commonwealth's Electric Facility Siting Board siting which does not require a health impact review on new energy projects. Mr. McDonald said that he will see if Dr. Jones may be able to assist with this concern.

Dr. Cosgrove suggested a letter to the editor noting that, when using a gas stove, a window should be left open especially in newly constructed, air tight homes.

Update on Tobacco Regulations Discussion from July Meeting

Dr. Epstein called into order a public hearing on the Board of Health's existing Article #1 – Regulations Affecting Smoking and the Sale and Distribution of Tobacco Products in Needham. Dr. Epstein officially opened the hearing at 8:00 a.m.

There were no members of the public present at the hearing. The Board of Health and the Public Health Division staff members discussed the proposed revisions to the existing tobacco regulation. The proposed revisions include inserting the definition of workplace, which had previously been removed due to a copying error when the regulation was last revised in July 2018.

While reviewing the definition of workplace, the Board discussed whether to increase the area outside of a workplace where smoking is prohibited from 20 feet up to 50 feet. This setback distance exists to ensure that smoke does not migrate into the workplace area.

The Board requested that a further discussion occur in October and that a vote potentially occur at a public hearing in November.

The Board noted that for some establishments, patrons will need to smoke in their cars or in the further parking lots for downtown restaurants if the footage is increased.

Dr. Cosgrove made a motion to close the hearing at 8:20. The motion was seconded by Dr. Brown. The motion was carried. The vote was unanimous.

Concussion Draft Prevention Regulation Discussion

Mr. McDonald reported that Ms. Zike and Ms. Kerry Dunnell have been working on the concussion regulations. The draft, in the Board packet, will be discussed with the Park and & Recreation Board at its October meeting. The Board of Health vote on the regulation is scheduled for the October meeting. Mr. McDonald requests that, following the BOH vote, a member of the BOH will attend the Park & Recreation Board meeting with him. Enforcement of the regulation may include a fine and suspension of field access if the concussion education is incomplete or if the Health Division has not been informed in a timely manner when a concussion occurs.

Dr. Epstein said that restricting the fields may be a Park and Recreation Board decision. Mr. McDonald noted that might not be the case since, if the health and safety of an athlete is at risk due to lack of coach training, the issue might be in the Health Division jurisdiction. Mr. McDonald will clarify with the Town Counsel before the electronic draft is sent to the Board and will advise in an email about the Town Counsel's advice.

Dr. Epstein recommended a new app that allows parents to assess concussion risk. Ms. Zike will also include other CDC data in the parental information packet. Dr. Epstein volunteered to provide training and feels his colleague, Dr. Stern, will also volunteer based on their work with soccer teams.

Dr. Brown recommended free apps for incident reporting and will provide some samples. Dr. Epstein recommended a longer term goal of getting IT to build a Health Division app if possible.

Mr. McDonald will send the final packet electronically to the Board for approval prior to the October meeting. Mr. McDonald noted we have to emphasize the purpose of the new regulation, including long term health effects of concussions on the public's health. Dr. Epstein requested citations as a part of the electronic draft.

Board of Health Goals for FY 2019 and FY 2020

Mr. McDonald said the goals should be specific and measurable. Mr. McDonald will update the Board on the status of the 2017-2018 goals at the October meeting.

(Fire alarm interrupts meeting at 8:22; 8:31 meeting resumes with inhabitable properties.)

Uninhabitable Properties
There were no persons present for the potential hearing at 8:20 a.m. That time slot was reserved if anyone wished to challenge the Director of Health & Human Services designation (while acting as the agent of the Board of Health) that an apartment unit in Needham was a "Dwelling Unfit for Human Habitation" with conditions specified in the order letter regarding "Conditions Deemed to Endanger or Impair Health or Safety".

Having reviewed the documentation and the order letter, the Board of Health formally voted to uphold the determination of Mr. McDonald. **Dr. Brown made a motion to uphold Mr. McDonald's determination. Dr. Cosgrove seconded that motion. The motion carried, and the vote was unanimous.**

From January to May 2018 there was an ongoing discussion with the Attorney General's Housing office about five abandoned properties on Riverside Street. These properties were finally put on the market in August. They have been sold to a developer and will likely be redeveloped and be sold as market rate properties.

Another extended discussion with the Attorney General's Housing Office was about the property at 228 Marked Tree Road. The owner's lawyer agreed to comply with a specific time frame to remedy the housing code violations. Mr. McDonald noted that this is a very positive outcome as it will result in a property refurbished to code rather than sold after being abandoned.

Emergency Management
Mr. McDonald noted that the Public Health Division shares responsibility for the town-wide emergency preparedness with the Needham Fire Department. Town-wide services and priorities fall under the bailiwick of the Select Board. Additional funding will also be requested in this year's budget cycle and Mr. McDonald would like the Board of Health's support so that emergency management does not crowd out other priorities within the Health and Human Services Department's budget request. The Board agreed to support Mr. McDonald as needed at meetings with the Select Board and Finance Committee and to ensure that emergency management is a town wide priority.

A discussion ensued on the need for more dedicated time to support Emergency Management, and how a full-time staff member could fully support those efforts. Ms. Rebecca Ping, the part-time emergency management staff person, has been recalled to active duty in the Navy for a year. Mr. McDonald said that a full-time position is justified. Dr. Epstein said that the need for the work is more than a part-time position can support.

Dr. Brown mentioned that the Lawrence-Andover gas explosions last night are a good reminder of the importance of emergency management in local communities. Dr. Cosgrove noted that the same incident can be used to push back on the unfixed gas leak issues in Needham.

Farmers Market Update
Mr. McDonald led a discussion on the need to be responsive to the community's needs by continuing to improve the Public Health Department's processes. In spring 2018, the application for mobile food vendors was shortened from 20 pages to 10. In 2019, without loosening the food compliance codes, the Public Health Division will explore some possibilities for improving the farmers market. Some possible

options may be: exceptions for cold storage for vendors who can only use coolers but agree to regular temperature monitoring; formalize bathroom access with a manager agreement with Walgreens so that prepared food can be sold, or failing this option, request Select Board funding to keep Town Hall bathrooms open especially; and a single vendor application form will be used for both the Market Manager and the Public Health Division; and continue to promise a faster turnaround time if the complete application is submitted by an early deadline.

Dr. Epstein supported Mr. McDonald's contention that more support from IT with online systems would allow Public Health Division staff to process more applications and devote more time to other important work. Mr. McDonald noted that the Town has very strict conditions under which Town departments may utilize an electronic payment system which accepts credit cards.

New Business

Dr. Cosgrove inquired if the Board has regularly appointed Mr. McDonald as the Board's agent under MA 111. Mr. McDonald noted the initial appointment was done just before he started in 2015 and the Board has signed the appropriate paper designating him as agent with Ms. Gurge as his backup on a roughly annual basis since that time. The last time the Board of Health made such a decision was in January 2018.

Next Meetings are:

- **October 18 7-9 am**
- **November 16 7-9 am**

Dr. Brown made a motion to adjourn the meeting. Dr. Epstein seconded that motion. The motion was carried. The vote was unanimous. The Board adjourned at 9:01 am.

Minutes Respectfully Submitted,

Faith Crisley, Recording Secretary

Carol Read, M.Ed., CAGS, CPS **September 2018**

Substance Use Prevention and Education ~ Initiative Highlights

Needham NPHD, Needham SPAN and Substance Abuse Prevention Collaborative (SAPC) grant* collaboration with the towns of Dedham, Needham, Norwood and Westwood**.**

SAPC grant

Town coalition meetings:
Dedham coalition: *No meeting scheduled*
Impact Norwood coalition: *No meeting scheduled*
Westwood Cares coalition: *No meeting scheduled*
Needham SPAN coalition: September 25th – *Family leave conflict*

SAPC program, capacity building and strategy implementation preparation:
(1) Alcohol Regulation templates (Section 15 and Section 12) SAPC Public Health and Chiefs of Police meeting planning (2) SAPC regional alcohol *compliance check program*- press release draft (3) TIPS training sessions November 5th planning/coordination (2 sessions) including: location confirmation, flyer final edits, licensee email database update (4 towns) with mailing address updates for hard copy mailing, Survey Monkey site registration monitoring and communication with Leadership Team (4) *PhotoVoice*: final photo display planning, caption identification for photos, outreach to Mother Brook Arts Center, November 15th event- Needham location outreach (5) Dedham DFC grant award support, information gathering for Program Director position hiring process. **Pending:** AlcoholEdu for High School students fall launch- grade 9 - capacity building with Health Education Directors | AlcoholEdu for Parents, program engagement options.

SAPC Youth Engagement Intern meetings: September 5th, 10th, 12th and 28th.
Emily Sanders, BUSPH, MPH candidate. SAPC Youth Engagement intern, *Photo Voice* program. Review: youth photos- final submissions, strategic planning for community displays (Dedham and Needham), event flyer design and youth town specific presentations. TIPS trainings: alcohol licensee email updates for flyer distribution. TIPS flyer mailings, USPS.

Dedham Public Health Department: September 5th Jessica Tracey and Cathy Cardinale, Public Health Director. Review of DFC grant Notice of Award (NOA) compliance components including programmatic (prevention strategy implementation and reporting), financial (tracking and reporting and funding reimbursement mechanisms) through the U.S. Department of Health and Human Services (HHS) Department of Payment Management (DPM). Annual award: $125, 000.

SAPC Alcohol Policy: September 7th Conference call D.J. Wilson, Attorney Massachusetts Municipal Association (MMA) and MassTAPP consultant. Review Needham SAPC Leadership Team goals related to alcohol regulation enhancements, including: (1) defined penalties for sales to minors (2) strategies to increase compliance rates by checking all patron identification under 35 years of age (3) intervention strategies to prevent over serving and driving under the influence.

SAPC Leadership Team- Alcohol Access team: September 10th D.J. Wilson, Attorney MMA, MassTAPP consultant. Chief Bill Brooks, Norwood facilitator. Chief Jeffrey Silva, Westwood (absent) Chief Michael D'Entremont, Dedham, Deputy Chief Mike Buckley and Chief John Schlittler, Needham. Bi-annual regional alcohol licensee compliance check initiative to impact retail access to alcohol. Alcohol Regulation current status and goals for regulation enhancement to include defined penalties for sales to minors. (continued)

Intervention strategies to prevent over serving and DUI occurances and mandatory in-person RBS/TIPS training. Review and discussion of bi-annual compliance check *fall* program protocols including operative recruitment, procedures to inform licensees and town leadership on initiative and outcomes. In collaboration with Public Health Directors, Linda Shea, Westwood, Sigalle Reiss, Norwood, Cathy Cardinale, Dedham, Tim McDonald, Needham and prevention coalition leaders Catherine Delano, Needham DFC and Aubrey Ciol, Norwood DFC.

SAMHSA- CAPT training: September 13th *Webinar* Substance Abuse Mental Health Services Administration-Center for the Application of Prevention Technologies: *Creating Compelling Prevention Messages: Using Your Community's Context to Strengthen Communications.* Skill building: (1) Creating persuasive communications with contextual community information (2) Key elements of effective prevention messages (3) Using data to enhance the impact of prevention messages. Gisela Rots, CAPT Northeast Team Coordinator and Jessica Goldberg, TA Specialist.

St. Sebastian's School, Parent Guild: September 17th Conference call. Jeanne Mackenzie, President Parent Guild. Request for information and resources related to e-cigarettes and vaping devices and options for speakers to presentation health information to parents and students. Resources provided, in person meeting dates and times presented.

Town of Dedham Public Health Department: September 20th DFC grant award breakfast, Endicott Estate. SAMHSA- ONDCP five (5) year underage substance use prevention award, $125,000 annually. Presentations of the DFC grant goals by Jessica Tracy, Public Health nurse and Mike Butler, Dedham Board of Selectman. Attendees: Cathy Cardinale, Public Health Director, Police Chief Michael D'Entremont, Fire Chief William Spillane, Superintendent Mike Welch, James Kern, Town Administrator, Gail Kelley, Director DPS Health, Fred Newton, President, HOPE House, Christine Hamilton, Fallon Ambulance, Monica DeWinter, Dedham- DFC parent liaison and nine additional key stakeholder representatives.

Norwood Public Health Department: September 28th Aubrey Ciol, Sigalle Reiss, Karen Regan. SAPC Review and discussion to build capacity for TIPS training alcohol licensee attaendance, electronic and hard copy flyer distribution for usps mailing, AlcoholEdu for High School students fall launch, Health Educator outreach and PhotoVoice event promotion November 15th Mother Brook Arts. Impact Norwood coalition review of 2018/2019 community education program: demystifying the Teen Brain (3 evening forums October, March 2019 and May 2019) Ocotber forum Dr. Ruth Potee.

Needham Public Health Division:

NPHD – SPAN initiatives:

NPHD programs meeting preparation outreach for research and resource gathering:
(1) NPHD August monthly report (2) BOH meeting minutes edit- Read segment (3) ED outreach to BIDN and NWH ED medical directors regarding patient services related to substance use detox and medical clearance prior to admission to inpatient treatment for SUD and/or mental health conditions. (4) Review confidentiality draft protocols for Public Health staff, Social Workers and HHS Division operations.

Needham Public Health Division meeting: September 7th Tim McDonald, Director, Department of Health and Human Services. Review of office move from the CATH to the RRC, review of the Public Health division communication protocols.

Community Crisis Intervention Team (CCIT): September 12th Core Team meeting, Needham Police Department. Facilitator: Lt. Chris Baker, Donald Anastasi, Eddie Sullivan, Donna Carmichael and Tiffany Zike, Public Health nurses, CATH Social Workers: Jessica Moss, Kerrie Cusack and Kristen Lindley, Needham Police officers: John McGrath and Matt Doukas and Ben Gross Riverside EST. Stakeholder collaboration to support residents navigating acute and chronic substance cue use disorders and/or mental health conditions. NPD review of acute and chronic mental health transport protocols to BIDN and NWH, barriers to ED transitions.

Needham Board of Health: September 14th Directors Report, staff public health initiatives, resident support programs, prevention reporting and BOH discussion of August agenda items for follow-up including SAPC regional alcohol compliance check data.

SPAN – SAPC capacity building: September 20th Review of SAPC Strategic Plan, Logic model strategies to impact Intervening Variables indicated in Needham underage alcohol use including: (1) Community Norms favorable to use (2) Low perception of harm (youth and parents) (3) Access to alcohol (retail and social). Review of SPAN Logic Model and strategies, discussion of collaboration and partnership to build engagement on SAPC strategies implementation in Needham. Catherine Delano, SPAN Program Director, Karen Shannon, Monica DeWinter, SPAN Project Coordinators, Karen Mullen and Maureen Doherty, NPHD Project Coordinators.

Community outreach and support

Resident Support: Respond to calls or meeting requests related to mental health conditions and/or substance use disorder. Referral to counseling, assessment, treatment and recovery resources. 0 requests in September.

Vacation days: (1) day ~ September 4th
Bereavement leave: (5) days

Respectfully submitted by Carol Read October 15, 2018

*SAPC technical assistance calls, coordinator meetings, and compliance related to the SAPC grant program are extensively documented in the BSAS-SAPC online quarterly reports.

Needham Public Health Division

September, 2018 Monthly Report

Maryanne Dinell- Traveling Meals Program Coordinator

Monthly

Description	*Reason*	*Notes/Follow-Up (ongoing, completed, etc.)*
Month of September, 2018	Residents of Needham, needing help with their daily meals.	37 clients on the Traveling Meals Program 26 Springwell Elder Services, Waltham clients 10 private pay clients - Needham residents
540 2- meal packages were delivered in Sept. 2018	21 Clients receive meals 5 times a week 15 Clients receive meals 3 days a week 1 Client receives meals for 7 days	408 meals delivered to Springwell Clients 132 meals delivered to private pay residents Total #5400 meals delivered @ 5.62 per meal =cost of $3034.80
4 new clients on the Program	3 are Springwell consumers 1 Private Pay	3 expected to be short term 1 long term
3 Clients no longer need Program	3 Consumers into nursing homes- 1 Consumer no longer able to remain in their home 2 Consumers needs more care than family can handle-	3 Springwell Consumers on Program since 2012, 2013, and 2014

Category		*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*FY '18 Total*	*1760*	
Meal Delivery		560	660	540										7759	1220	
General Telephone Calls-received		29	62	22										547	113	
Assistance Calls-to Springwell		4	2	2										51	5	
Not at home at delivery		4	3	6										38	13	
911		1	0											0	1	

Category		*Jul*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*FY '18 Total*	*1760*	

Meetings, Events, and Trainings

BI	*Type*	*Description/Highlights/Votes/Etc.*	*Attendance*
Board of Health Meeting		Monthly meeting held at PSAP	Staff and Board Members

Donations, Grants, and Other Funding [List any donations received, grants funded, etc. over the past month.]

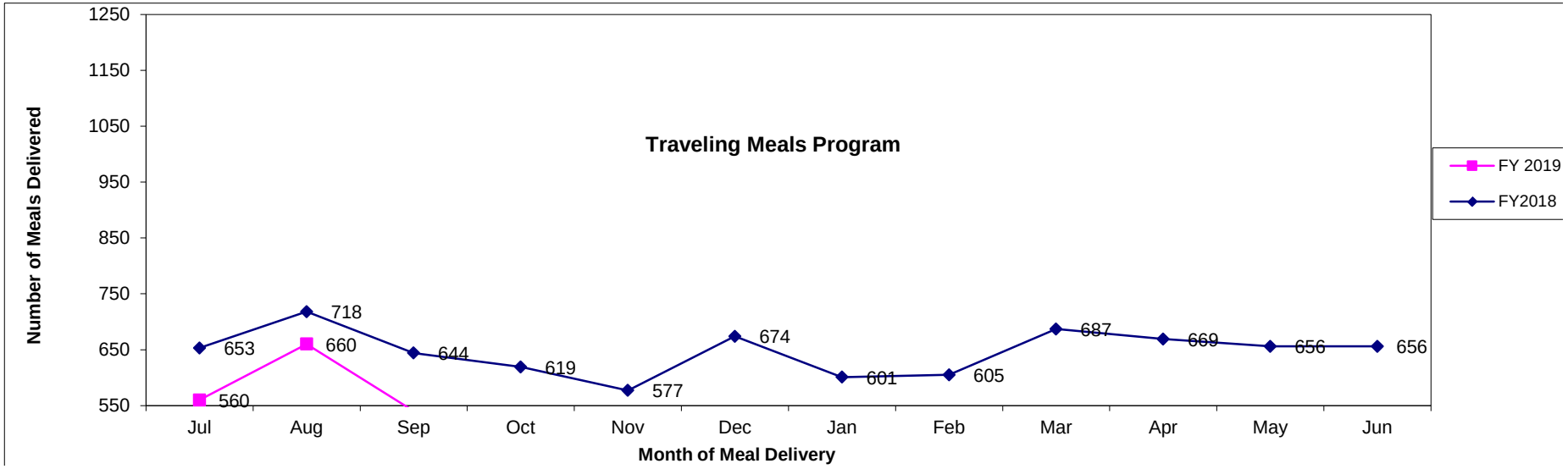
Description	*Type (D,G,O)*	*Amount Given*	*Source*	*Notes*

Traveling Meals Program

September, 2018

Month	# Meals FY2018	# Meals FY2019	FY18 Cost	% Change # Meals
Jul	653	560	$3,147.20	-14%
Aug	718	660	$3,709.20	-8%
Sep	644	540	$3,034.80	-16%
Oct	619			
Nov	577			
Dec	674			
Jan	601			
Feb	605			
Mar	687			
Apr	669			
May	656			
Jun	656			
Totals:	7,759	1,760	9,519.00	

Projected-12 Mo.	
$	12,588.80
#	7,040



Needham Public Health Division

September 2018

Assist. Health Dir. - Tara Gurge
Health Agents - Diana Acosta and Brian Flynn

Activities

Activity	*Notes*
Animal Permit	**1 – Animal Inspection conducted:** - #28 Clarke Road – Christina Burns -2 chickens **1 – New Animal Permit issued for:** - #28 Clarke Road **19 – Inspections conducted by ACO Parsons and barn book to be submitted to the state – No issues found.**
10-Day Emer. Beaver/Muskrat Permit	**1-10 – Day Emergency Beaver or Muskrat Permit issued to:** - **Chris Seariac (Town Water and Sewer Dept.) for Beaver Solutions to remove beaver near the West St. Pump Station/Culvert. Also extended permit to allow the installation of Exclusion/Diversion fences to discourage beaver recolonization. Conservation also approved.**
Bodywork Practitioner Appln Reviews (On-going/New)	**1 – Bodywork Practitioner Permit application received from:** - Barbara Falla- To practice Reiki at CATH.
Bottling Permit Application/ Inspection Conducted	**1 – Application Received and Inspection Conducted** - **Coca Cola** – Diana coordinated an inspection with the state. Inspection found very minor issues that were corrected on site or had work orders put in. Awaiting approval from the state before issuing permit. (In process.)
Demo Reviews/ Approvals	**9 - Demolition sign-offs:** - #46 John Street - #32 Rybury Hillway - #245 Country Way - #66 Tudor Road - #33 School Street - #107 Marked Tree Road - #215 West Street - #42 Park Ave - Holmes St.
Emergency/Fire Dept. Calls	**0 – Emergency calls received from Fire Dept.**
Food – Needham Farmers Market New Permits/Insp. conducted (Stephanie or Diana to conduct weekly FM inspections throughout the	**1 – New Needham Farmers Market Permit Issued to:** - Sweet Tahini **41 – Farmers Market Inspections** - Stephanie performed weekly inspections of each permitted Farmers Market Vendors and also the annual Harvest Fair. **10 - Harvest Fair food vendors were combined with the Farmer's Market this year. (See Permitted food vendors noted below.)**

season.)	
Food – Temporary Food Event Permits	**19 – Temporary Food Permits issued to:** - Jog your memory 5k @ Mitchell Elementary - Great Hall Performance - Pie in the Sky @ Coldwell Banker - Carter Nursery - Needham Junior Football - Hot dog concessions - Hearth @ Harvest Fair - Hearth @ Needham Community Farm - Girl Scouts of Needham Ice Cream Event - Operation Smile Club @ Harvest Fair - Touchdown Club - Masala Art @ Harvest Fair - Dedham Savings @ Harvest Fair - Coldwell Banker @ Harvest Fair - Newton Needham Chamber @ Harvest Fair - Abbott's @ Harvest Fair - Woops Macarons @ Harvest Fair - Touchdown Club (Virgiligo's Echo Bridge) - NHS Friends of Music - Park and Rec - Kid's Night Out
Food – Food Permit Plan Reviews	**2 – Food Permit Plan Review applications received for:** - **Epicurean Feast** @ #250 First Ave location – Looking to open an 'unmanned' food establishment. **UPDATE**: State does not allow. Will change to a vending machine, which the state will be required to review their proposal and permit their vending machine. - **Gyro & Kebab House Greek Cuisine Needham –** Food Permit Plan Review packet received. Still in permit plan review process. Also working with Building and Zoning Depts. re: Special Permit requirements.
Housing – Complaints/ Follow-ups	**3/3 – Housing Complaints/Follow-ups conducted at:** - **#172 D Linden Street – UPDATE:** No longer need to communicate with attorney. Waiting to verify that all work orders were completed. Have been in touch with Gary Kuphal re: status of on-going issues. (Pending.) - **Webster Green 108 S (On-going) –** Apartment has been cleaned. Waiting to schedule final inspection to verify it is now up to code. (Pending.) - **#1297 Central Ave. -** Received message from Sandy that a neighbor complained about a home that appeared abandoned and dilapidated. Diana passed by the house and took photos - did not see anything outstanding that would trigger the junk by-law/nuisance regulation. The home appeared to be getting some work done as there was a dumpster in the driveway, but otherwise appeared to be in good condition.
Nuisance – Complaints/ Follow-ups	**5/5 – Nuisance Complaints/Follow-ups conducted for:** - **#324 Greendale Ave. - (On-going**) – **UPDATE**: Health Division stopped by residence. Met with owners' sister, who is now in the loop. She has cleaned up driveway and backyard. Trampoline was removed from the front yard and discarded. Cars were taken off the property. Only barrier is money for repairing the broken fence. (Still in process.) - **Pickering Street –** Resident complained that there is a loud, constant sound coming from the Verizon building on Pickering. Tara and Diana conducted a site visit and did not think the sound would violate the noise by law (which is 10 Db above background noise). A group of children were playing across the street and were louder than the buzzing sound. The

	resident was offered to borrow our equipment to check the sound level during after work hours, but she did not put in the request yet to date. The resident decided to instead call Verizon to see if they could work on muffling the sound. - **#115 Wilshire Park –** Neighbor came into office with recent photos of the property and reports that there are still pests in the area. The amount of things accumulated in the backyard (i.e. trees/brush) is damaging his fence and the neighbors have put up a 'spite fence.' Tara was in contact with Dave Roche to assess the situation. **UPDATE**: Owner removed other trash items noted. We also encouraged him to relocate the reported 'spite fence.' - **#180 Central Ave** - Anonymous complaint - Unregistered car on property that is "sinking into the ground". Called police department to check if the car is registered and they sent out someone the same day. - **#185 Brookside Road -** Neighbor called about house being abandoned and unkempt. Called and left message to complainant and found a public notice that the house is to be razed. Public hearing was held on September 13, 2018 where owner's notice of intent application was reviewed by conservation.
Pool –Pre-operation Inspection	**1 – Pool pre-operation follow-up inspection conducted at:** - Modera Needham (on Greendale Ave.)
Pool – New Permit Issued	**1 – Pool Permit issued:** - Modera Needham (on Greendale Ave.)
Septic Construction Permit	**1-Septic Construction permit issued for:** - #745 Central Ave.
Septic Trench Permit	**1- Septic Trench permit issued for:** - #745 Central Ave.
Septic – Plan Reviews	**1 – Septic Design Plan received for review:** - #61 Forest St. – Received proposed septic design plan for review. Need to submit revised plan in order to meet Mass DEP Title Five septic code requirements. (Revised plan pending.) Met with septic designer/installer. **UPDATE:** Revised septic plan submitted. Approval letter issued. Follow-up - Owner still looking into connecting to the municipal sewer line, which will need to be brought up the street.
Septic – Installer permit and test	**1 – Installer exam taken:** - Bob Roach **1- Installer permit issued:** - Bob Roach
Tobacco Insp. (Routine)	**3 – Routine Tobacco inspections conducted at:** - Needham Service Center - Sudbury Farms - Great Plain Ave Gas
Well Permits	**1 – New Irrigation well permit issued for the following property:** - #60 Wildwood Drive

Planning/Special Permit reviews	**2 – Special Permit Reviews conducted for:** - Major Project Site Plan Special Permit Amendment 2018-08, PEX Health and Fitness – No comments Memo sent. - Major Project Site Plan Special Permit Amendment 2018-09, Dr. Marcia A. Walker d/b/a Rx2Care Clinic. Comment Memo sent re: Demo./Renovation requirements, etc.
Zoning Board of Appeals Project reviews	**0 – Zoning Board of Appeal reviews conducted.**

Yearly

Category	*Jul*	*Au*	*S*	*O*	*N*	*D*	*J*	*F*	*M*	*A*	*Ma*	*Ju*	***FY '19***	FY' 18	*FY' 17*	FY' 16	*Notes/Follow-Up*
Biotech	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	2	2	Biotech registrations
Bodywork	0	0	0	0	0	0	0	0	0	0	0	0	**0**	14	6	11	Bodywork Estab. Insp.
Bodywork	0	2	0	0	0	0	0	0	0	0	0	0	**2**	6	4	3	Bodywork Estab. Permits
Bodywork	0	2	1	0	0	0	0	0	0	0	0	0	**3**	22	13	10	Bodywork Pract. Permits
Bottling	0	0	1	0	0	0	0	0	0	0	0	0	**1**	1	2	1	Bottling Permit insp.
Demo	12	13	9	0	0	0	0	0	0	0	0	0	**34**	105	112	110	Demo reviews
Domestic Animal Permits/Insp.	0	1	1	0	0	0	0	0	0	0	0	0	**2**	19	17	16	Animal permits/
	0	0	20	0	0	0	0	0	0	0	0	0	**20**	3	16		Inspections
Food Service	16	8	23	0	0	0	0	0	0	0	0	0	**47**	225	198	209	Routine insp.
Food Service	3	1	0	0	0	0	0	0	0	0	0	0	**4**	32	37	35	Pre-oper. Insp.
Retail	6	5	7	0	0	0	0	0	0	0	0	0	**18**	60	69	71	Routine insp.
Resid. kitchen	0	1	0	0	0	0	0	0	0	0	0	0	**1**	8	7	11	Routine insp.
Mobile	1	4	0	0	0	0	0	0	0	0	0	0	**5**	13	15	9	Routine insp.
Food Service	1	1	0	0	0	0	0	0	0	0	0	0	**2**	53	51	50	Re-insp.
Food Service/retail	2	1	0	0	0	0	0	0	0	0	0	0	**3**	171	177	176	Annual/Seasonal Permits
Food Service	7	12	19	0	0	0	0	0	0	0	0	0	**38**	163	158	107	Temp. food
	9	1	10	0	0	0	0	0	0	0	0	0	**20**	29	62	54	permits/Inspecti
Food Service	1	0	1	0	0	0	0	0	0	0	0	0	**2**	14	7	9	Farmers Market permits
	50	45	41	0	0	0	0	0	0	0	0	0	**136**	127	33	16	Farmers Market insp.

Food Service	0	2	0	0	0	0	0	0	0	0	0	0	**2**	20	13	21	New Compl/
	0	2	0	0	0	0	0	0	0	0	0	0	**2**	21	17	21	Follow-ups
Food Service	0	1	1	0	0	0	0	0	0	0	0	0	**2**	42	33	32	Plan Reviews
Food Service	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	0	3	Admin. Hearings
Grease/ Septage Haulers	0	0	0	0	0	0	0	0	0	0	0	0	**0**	24	24	29	Grease/ Septage Hauler Permits
Housing (Chap II Housing)	0	0	0	0	0	0	0	0	0	0	0	0	**0**	14	14	7	Annual routine insp./
	0	0	0	0	0	0	0	0	0	0	0	0	**0**	5	4	4	Follow-up insp.
Housing	2	4	1	0	0	0	0	0	0	0	0	0	**7**	22	7	18	New Compl./
	3	5	1	0	0	0	0	0	0	0	0	0	**9**	24	11	37	Follow-ups
Hotel	0	0	0	0	0	0	0	0	0	0	0	0	**0**	3	3	3	Annual insp./
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Follow-ups
Nuisance	2	5	5	0	0	0	0	0	0	0	0	0	**12**	42	30	44	New Compl./
	2	5	5	0	0	0	0	0	0	0	0	0	**12**	42	45	50	Follow-ups
Pools	1	4	0	0	0	0	0	0	0	0	0	0	**5**	12	13	9	Pool insp./
	1	5	0	0	0	0	0	0	0	0	0	0	**6**	7	8	3	Follow up
Pools	1	2	1		0	0	0	0	0	0	0	0	**4**	12	9	9	Pool permits
Pools	2	1	0	0	0	0	0	0	0	0	0	0	**3**	44	19	8	Pool plan reviews
Pools	0	0	0	0	0	0	0	0	0	0	0	0	**0**	7	6	4	Pool variances
Septic	0	0	0	0	0	0	0	0	0	0	0	0	**0**	5	18	8	Septic Abandon
Septic	1	0	0	0	0	0	0	0	0	0	0	0	**1**	2	5	9	Addition to a home on a septic plan rev/approval
Septic	0	0	0	0	0	0	0	0	0	0	0	0	**0**	28	43	23	Install. Insp.
Septic	0	0	0	0	0	0	0	0	0	0	0	0	**0**	1	0	3	COC for repairs
Septic	0	0	0	0	0	0	0	0	0	0	0	0	**0**	4	3	3	COC for complete septic system
Septic	6	4	0	0	0	0	0	0	0	0	0	0	**10**	51	62	61	Info. requests

Septic	0	0	0	0	0	0	0	0	0	0	0	0	**0**	2	6	8	Soil/Perc Test.
Septic	0	1	0	0	0	0	0	0	0	0	0	0	**1**	5	8	6	Const. permits
Septic	0	0	1	0	0	0	0	0	0	0	0	0	**1**	9	11	9	Installer permits
Septic	0	0	1	0	0	0	0	0	0	0	0	0	**1**	3	6	6	Installer Tests
Septic	0	0	0	0	0	0	0	0	0	0	0	0	**0**	3	7	3	Deed Restrict.
Septic	1	1	0	0	0	0	0	0	0	0	0	0	**2**	23	14	14	Plan reviews
Sharps permits/Insp.	0	0	0	0	0	0	0	0	0	0	0	0	**0**	9	9	10	Disposal of Sharps permits/
	0	0	0	0	0	0	0	0	0	0	0	0	**0**	7			Inspections
Subdivision	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	3	3	Plan review- Insp. of lots /
	0	0	0	0	0	0	0	0	0	0	0	0	**0**		1	0	Bond Releases
Special Permit/ Zoning memos	1	2	0	0	0	0	0	0	0	0	0	0	**3**	15	12	16	Special Permit/Zoning
Tobacco	0	0	0	0	0	0	0	0	0	0	0	0	**0**	11	12	13	Tobacco permits
Tobacco	4	1	3	0	0	0	0	0	0	0	0	0	**8**	18	25	25	Routine insp./
	1	0	0	0	0	0	0	0	0	0	0	0	**1**	3	6	7	Follow-up insp.
Tobacco	0	0	0	0	0	0	0	0	0	0	0	0	**0**	41	34	48	Compliance checks
Tobacco	0	0	0	0	0	0	0	0	0	0	0	0	**0**	4	2	4	New compl./
	0	0	0	0	0	0	0	0	0	0	0	0	**0**	4	2	4	Compl. follow-
Trash Haulers	0	0	0	0	0	0	0	0	0	0	0	0	**0**	14	26	30	Trash Hauler permits
Medical Waste Haulers	0	0	0	0	0	0	0	0	0	0	0	0	**0**	1	2	2	Medical Waste Hauler permits
Wells	0	2	0	0	0	0	0	0	0	0	0	0	**2**	2	7	6	Permission to drill letters/
	0	0	0	0	0	0	0	0	0	0	0	0	**0**	0	3	0	Well Permits

FY 19 Priority FBI Violations Chart (By Date)

Restaurant	Insp. Date	Critical Violation	Description
Comella's	7/16/2018	**28 - 7-206.13 (A) Tracking Powders, Pest Control & Monitoring** - A tracking powder pesticide may not be used in a food establishment.	**Kitchen** -Eliminate mouse infestation
Cookies By Design	9/21/2018	**9-3-301.11 (B) Preventing Contamination from Hands** - Except when washing fruits and vegetables, food employees may not contact exposed, ready-to-eat food with their bare hands and shall use suitable utensils such as deli tissue, spatulas, tongs, single-use gloves or dispensing equipment.	**Kitchen** - Need gloves -
Pollard Middle School	9/24/2018	**28-7-204.11 Sanitizers** - Chemical sanitizers, including chemical sanitizing solutions generated onsite, and other chemical antimicrobials applied to food-contact surfaces shall meet the requirements specified in 40 CFR 180.940. Chemical sanitizers shall not exceed manufacture's label instructions.	**Kitchen** - Sanitizer in 3 bay sink was low ~100 ppm - should be 150-200 ppm (green color on test strip) -
St. Sebastian's	9/27/2018	**33-3-501.15 (A) Cooling Methods** - Cooling shall be accomplished in accordance with the time and temperature criteria specified under 3-501-14 by using one or more of the following: placing food in shallow pans; separating the food into smaller or thinner portions; using rapid cooling equipment; stirring the food in a container placed in an ice water bath; using containers that facilitate heat transfer; adding ice or other effective methods	**Kitchen** - Tortellini was at 68 F - should be cold held in walk-in before being placed in the salad bar -

Needham Public Health Division

Accreditation Update
September 2018

October 16, 2018
Lynn Schoeff

Activity	Notes
Staff training	• None in September
Policies and procedures	• Extensive research and initial draft of: - Confidentiality for public health workers - Confidentiality for social workers - Confidentiality agreement for all HHS staff - Release of information form for HHS staff

Other activities this month:

- On September 21, attended a training to become a "Dementia Champion" to give community presentations about dementia.
- On September 24, attended a bidders conference at MetroWest Health Care Foundation.

Needham Public Health Department
Rachael Greenberg, Public Health Associate
September 2018 Monthly Report

Safety at Home Program

The Town continues to move forward its Safety at Home Program, which will provide home safety visits to reduce falls among older adults in Needham.

Program activities completed in September 2018 include:

- Began program roll-out
    - **Five pilot and two full program visits completed to date**
    - Data from visits collected and recorded
- Held program launch on 9/6/18 at CATH
    - Needham staff presented about Safety at Home staff
    - Speaker from Beth Israel presented on fall prevention best practices in the home
    - Six tables of community resources (from the Town and community partners) were present
    - **Approximately 40 individuals attended the event**
        - Nine attendees had fallen previously
- Continued improvement on program protocol and forms
- Continued development of an evaluation plan
- Promoted program widely
    - Met with Needham Police Department to share program information
- Developing plan to offer Matter of Balance sessions year-round to program participants (and Needham residents overall), in collaboration with Aging Services
- Regular team meetings continued

Housing Authority Assessment

The Town is continuing work began during Summer 2017 to identify assets and needs of residents of the Needham Housing Authority. Prior work included key informant interviews and limited focus groups.

In May, the Town held six focus groups – two in English, two in Mandarin, and two in Russian. 14 English-speaking participants attended and 4 Mandarin-speaking individuals attended. No Russian-speaking individuals attended, so the Town is planning to reach out to identified Russian-speaking leaders within the Housing Authority to conduct interviews, in lieu of focus groups. However, despite several attempts by the Housing Authority's Resident Coordinator, no Russian speaking individuals have volunteered to speak with the Town. The Town will continue trying different avenues to reach this population as it works on the survey. The Town will disseminate a survey in the fall to obtain broader, quantifiable data. During September, staff continued developing the survey with an external consultant. The survey will be distributed to Housing Authority residents in October.

Accreditation

- To assist with the Town's accreditation efforts, research continues to be conducted to begin work on a Community Health Assessment.
- Beth Israel Deaconess – Needham, and its vendor, JSI, have agreed to partner with the Town on its 2019 Community Health Needs Assessment to reduce costs for both parties and leverage resources. Beth Israel's assessment will be used to inform the Town's Community Health Assessment.
    - In September, Needham staff prepared for the formal assessment work to begin in October.

AARP Grant

In July the Town was awarded a small five-month grant from AARP Massachusetts to create a display and brochure with information regarding accessory dwelling units. The display will be placed in several town locations during the grant period and a kickoff event will be held.

The following activities took place in September:

- Review and editing of display and brochure (both text needed and drafts from graphic designer)
- Began planning launch event, set for October 17th at CATH

Other

- Participating in the 18-week Managing Effectively in Today's Public Health Environment course, conducted by the Local Public Health Institute of MA.

Needham Public Health Division

Unit: Substance Use Prevention

Date: September 2018

Staff: Catherine Delano, Karen Shannon, Karen Mullen, and Monica DeWinter

Summary: SPAN meetings (including the Steering Committee and Needham Parents Care) were held. SALSA and 5th Quarter had a great start to the year. Highlights are below.

Activities and Accomplishments

Activity	Notes
Prevention Team Meetings	Agenda for SPAN Steering Committee Meeting and annual initiatives with Carol Read
NHS Admin. Meeting w/Dir. Kathy Pinkham	Discussed Life Skills Conference and "If They Had Known" film & panel discussion for 2018-19 school year.
Wellesley High School Meeting	Met with Dr. Kathy Pinkham and WHS teachers/organizers of annual "Seminar Day" to prepare for NHS Life Skills Conference.
SPAN Steering Committee Meeting	Confirmed SPAN Meeting agenda
SPAN Quarterly Meeting	Screened "If They Had Known" documentary, discussed harm reduction.
5th Quarter – 9/28	5th Quarter event for Needham teens- Planned and executed substance free event after V. Football game **(over 200 students attended)**
SALSA Trainer Meeting	Confirmed September Training agenda & materials
SALSA Leadership team meetings (2)	Discussed 2018-19 objectives and events for year
SALSA High Rock Project	Communicated & discussed project notes/materials to new project leader
Needham Parents Care	First meeting of new school year. Discussed global focus for NPC for this year.
Needham Youth Diversion	Worked with the Program Coordinator to support with marketing materials

Public Health Nurse Report - AugustPlanning FY2019
Donna Carmichael and Tiffany Zike

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COMMUNICABLE DISEASES:	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	Apr	MAY	JUN	T19	T18	T17
BABESIOSIS		3											3	4	2
Borrelia Miyamota													0	0	0
CAMPYLOBACTER													0	14	7
CRYPTOSPORIDIUM													0	1	0
Cyclosporiasis													0	1	0
Dengue													0	0	1
E-Coli													0	0	0
EHRLICHIOSIS/ HGA	1	1											2	2	2
Enterovirus													0	1	1
GIARDIASIS													0	1	2
Haemophilus Influenza													0	1	1
HEPATITIS B		1											1	8	8
HEPATITIS C	1		3										4	14	21
Influenza													0	211	108
Legionellosis													0	2	0
Listeriosis													0	0	0
LYME	13	7	2										22	53	44
MEASLES													0	0	0
MENINGITIS													0	0	0
Meningitis(Aseptic)													0	1	2
Mumps													0	0	0
Noro Virus													0	3	2
PERTUSSIS	3												3	1	4
SALMONELLA			1										1	3	2
SHIGA TOXIN													0	0	1
SHIGELLOSIS		1											1	0	0
STREP Group B													0	1	0
STREP (GAS)													0	5	0
STREP PNEUMONIAE													0	3	0
TUBERCULOSIS													0	0	0
TULAREMIA													0	0	1
Latent TB- High Risk	1												1	0	1
Varicella	2	1	1										4	12	10
Vibrio			1										1	0	1
West Nile virus													0	0	0
Zika													0	1	1
TOTAL DISEASES	21	14	8	0	0	0	0	0	0	0	0	0	43	343	221
Revoked Diseases Investigated			1										1	6	13
Contact Investigation	4												4	4	1

Public Health Nurse Report - AugustPlanning FY2019
Donna Carmichael and Tiffany Zike

ANIMAL TO HUMAN BITES	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	Apr	MAY	JUN	T19	T18	T17
DOG	6	3	4										13	42	15
CAT													0	0	0
BAT													0	8	5
SKUNK													0	0	0
RACOON													0	0	0
other													0	1	1
TOTAL BITES	6	3	4	0	0	0	0	0	0	0	0	0	13	51	22

IMMUNIZATIONS	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	FY19	FY18	FY17
B12	2	2	2										6	24	22
Flu (Seasonal)			284										284	522	674
Polio		4													
TDap		3											3	0	1
Varicella													0	2	0
Consult	49	50	90										189	319	592
Fire/Police	20	7	15										42	59	80
Schools	2	8	30										40	42	106
Town Agencies	25	20	20										65	185	246
Community Agencies	2	15	25										42	32	160

ASSISTANCE PROGRAMS	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	FY19	FY18	FY17
Food Pantry		1	2										3	13	20
Food Stamps			0										0	0	4
Friends			0										0	0	0
Gift of Warmth	1		2										3 ($832)	20($7250)	11
Good Neighbor			0										0	5 $425/fam	8
Park & Rec			0										0	1	2
Salvation Army			0										0	0	0
Self Help	2	2	1										5	34	46

Gift of Warmth Donations

Gift Cards

Public Health Nurse Report - AugustPlanning FY2019
Donna Carmichael and Tiffany Zike

WELLNESS PROGRAMS	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	FY19	FY18	FY17
Office Visits	56	49	34										139	467	481
Safte Visits	0	3	2										5	10	7
Clinics	0	0	0										0	0	0
Housing Visit	1	1	0										2	15	6
Housing Call	0	3	3										6	110	37
Camps-summer	6	7	0										13	60	50
Tanning Insp	0	0	0										0	0	0
Articles	1	0	1										2	3	3
Presentations	1	1	6										8	16	0
Cable	0	1	1										2	2	5

EMPLOYEE WELLNESS	July	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	FY19	FY18	*FY17*
BP/WELLNESS - DPW/RTS	0	0	10										10	148	169
CPR/AED INSTRUCTION	0	0											0	0	31
Police Weights	0	0											0		
First Aide	10	8											18		
Total People	10	8	10	0	0	0	0	0	0	0	0	0	28		
Community Education Hours															
HEALTH ED Tick Borne	50	20											70	132	90
HEALTH ED Mosquito Borne	50	20											70	135	80
HEALTH ED FLU	0	0											0	289	160
GENERAL HEALTH EDUCATION	20	10											30	186	258
Total Hours	140	66	20	0	0	0	0	0	0	0	0	0	170	1077	954

Public Health Nurse Report - AugustPlanning FY2019
Donna Carmichael and Tiffany Zike

MEETINGS, EVENTS, TRAININGS

Title	*Description/Highlights/Votes/Etc.*
CCIT	Monthly Meeting-community meeting
Emergency Planning	Planning x1
	Meeting with Rebecca for LEPC
	MRC Meet and Greet
DVAC	Meetings x1
	Harvest Fair
	Cable series filming
Concussions	Meeting x2
Community Events	Harvest Fair
	Hair and Skin Presentation at CATH
	Lunch and Learn- All about the Flu
	BU Student-Government Event
	CATH Open House
Flu Clinics	Sept 20th -CATH
	Sept 26th -Rosemary
	Office Appts
Healthy Aging	Lunch and Learn
Infection Control Meeting	BID Needham
ITWA	Meeting x1
Webinar	Influenza x2
	Hep A

Emergency Planning:

NC 7
Region 4AB
LEPC

From: T Stephen Jones [mailto:t.stephen.jones@gmail.com]
Sent: Monday, September 17, 2018 2:08 AM
To: T. Stephen Jones
Subject: 75 Boards of Health concerned about risks of natural gas -- representing 40.1% of Commonwealth population

The Somerville Board of Health has sent a letter to Governor Baker about their concerns about the health risks of "natural" gas

With the 75,754 people represented by the Somerville Board of Health

75 Boards that have communicated with the Governor about their concerns about the health risks of "natural" gas

those 75 Boards represent ***2,626,440*** residents of Massachusetts

that make up ***40.1%*** of the population of the Commonwealth

and the natural gas explosions and fires in Lawrence, Andover, and North Andover are likely to make more Boards of Health consider the risks of "natural" gas

Steve Jones -- Sierra Club volunteer

Towns & Cities whose Board of Health has signed on to group letter or written own letter to Governor Baker about health risks of natural gas

Population represented by Boards that have sent letter to Governor	2,626,440	Mass. Population	40.1%	% Mass population represented by Boards sent letter
		6,547,629		

#	Town/City	Population	Signed on or wrote own letter	#	Town/City	Population	Signed on or wrote own letter
1	Abington	15,985	Signed on May 2017	38	Holyoke	39,880	Signed on Jul 2017
2	Adams	5,515	Signed on Jun 2017	39	Lanesborough	3,091	Signed on Aug 2017
3	Agawam	28,438	Own letter Jun 2018	40	Lexington	31,394	Own letter Jun 2017
4	Amherst	37,819	Own letter Oct 2017	41	Longmeadow	15,633	Own letter Aug 2018
5	Arlington	42,844	Signed on May 2017	42	Ludlow	21,103	Signed on Apr 2017
6	Ashburnham	6,081	Signed on Jun 2017	43	Methuen	47,255	Signed on Sept 2017
7	Ashby	3,074	Signed on May 2017	44	Millis	7,891	Signed on Apr 2017
8	Ashfield	1,737	Signed on Jul 2017	45	Milton	27,003	Own letter May 2018
9	Athol	8,265	Signed on May 2017	46	Natick	32,786	Own letter Sept 2017
10	Attelboro	43,493	Signed on Apr 2018	47	Newton	85,146	Own letter May 2017
11	Bedford	13,320	Signed on Jun 2017	48	Norfolk	11,227	Signed on May 2017
12	Belchertown	14,649	Own letter Aug 2018	49	North Adams	13,708	Own letter Mar 2018
13	Bellingham	16,332	Signed on Apr 2017	50	Norton	19,031	Signed on Apr 2017
14	Billerica	40,243	Signed on Jun 2017	51	Norwood	28,602	Signed on May 2017
15	Boston	617,594	Own letter Jun 2017	52	Northampton	28,549	Own letter Dec 2017
16	Brookline	58,732	Own letter May 2018	53	Peabody	51,251	Own letter Aug 2018
17	Buckland	1,902	Signed on May 2017	54	Peru	847	Own letter Aug 2018
18	Cambridge	105,162	Signed on Jan 2018	55	Pittsfield	44,737	Own letter May 2018

19	Canton	21,561	Own letter Jan 2018	56	Provincetown	2,642	Signed on May 2017
20	Carlisle	4,852	Signed on May 2017	57	Rehoboth	11,608	Signed on
21	Chatham	6,125	Own letter Mar 2018	58	Rockport	6,952	Signed on Jun 2017
22	Chelsea	38,861	Own letter Jul 2018	59	Salem	41,340	Own letter Jul 2018
23	Chicopee	55,298	Signed on Oct 2017	60	Saugus	26,628	Signed on 2017
24	Chilmark	866	Signed on Apr 2017	61	Shelburne	1,893	Signed on Aug 2017
25	Cohasset	7,542	Signed on July 2017	***62***	***Somerville***	***75,754***	***Own letter Aug 2018***
26	Concord	17,668	Signed on May 2017	63	Springfield	153,060	Signed on Apr 2018
27	Conway	1,897	Signed on Apr 2017	64	Stoughton	26,962	Signed on Oct 2017
28	Dalton	6,756	Own letter Oct 2017	65	Stow	6,590	Signed on Apr 2017
29	Dartmouth	34,032	Own letter May 2018	66	Townsend	8,926	Signed on May 2017
30	Deerfield	5,125	Signed on Apr 2017	67	Uxbridge	13,457	Signed on Aug 2017
31	Eastham	4,956	Signed on Aug 2017	68	Walpole	24,070	Signed on Aug 2017
32	Egremont	1,225	Signed on July 2017	69	Waltham	60,632	Signed May 2018
33	Essex	3,504	Signed on Apr 2017	70	Westfield	41,094	Signed on July 2017
34	Grafton	17,765	Signed on Apr 2017	71	Weston	11,261	Signed on Mar 2018
35	Great Barrington	7,104	Signed on Jun 2017	72	West Springfield	28,391	Signed on May 2017
36	Greenfield	17,456	Own letter May 2018	73	Weymouth	53,743	Signed on Apr 2017
37	Harvard	6,520	Signed on May 2017	74	Winthrop	17,497	Signed on Jun 2017
				75	Worcester	184,508	Own letter Jul 2018
					Updated - Sept 16, 2018		

Preparing letters to the Governor -- Acton, Falmouth, Lowell, Plymouth, Westborough, Westford, & Williamsburg - - - Pending Board decisions: Brockton, East Longmeadow, Easthampton, Fitchburg, Needham, North Attleboro, Wayland, & Wellesley

Published by Oxford University Press on behalf of the International Epidemiological Association
International Journal of Epidemiology 2013;42:1724–1737
doi:10.1093/ije/dyt150
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EARLY LIFE

Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children

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Accepted 25 June 2013

Background Since the meta-analysis on the association between indoor nitrogen dioxide (NO_2) and childhood respiratory illness in 1992, many new studies have been published. The quantitative effects of indoor NO_2 on respiratory illness have not been estimated in a formal meta-analysis since then. We aimed to quantify the association of indoor NO_2 and its main source (gas cooking) with childhood asthma and wheeze.

Methods We extracted the association between indoor NO_2 (and gas cooking) and childhood asthma and wheeze from population studies published up to 31 March 2013. Data were analysed by inverse-variance-weighted, random-effects meta-analysis. Sensitivity analyses were conducted for different strata. Publication bias and heterogeneity between studies were investigated.

Results A total of 41 studies met the inclusion criteria. The summary odds ratio from random effects meta-analysis for asthma and gas cooking exposure was 1.32 [95% confidential interval (CI) 1.18–1.48], and for a 15-ppb increase in NO_2 it was 1.09 (95% CI 0.91–1.31). Indoor NO_2 was associated with current wheeze (random effects OR 1.15; 95% CI 1.06–1.25). The estimates did not vary much with age or between regions. There was no evidence of publication bias.

Conclusions This meta-analysis provides quantitative evidence that, in children, gas cooking increases the risk of asthma and indoor NO_2 increases the risk of current wheeze.

Keywords Asthma, wheeze, gas cooking, indoor pollution, infant, review

Introduction

The association between adverse health consequences and indoor nitrogen dioxide (NO_2) exposure has been the subject of many studies. Indoor NO_2 exposure may increase the risk of acute and chronic respiratory illnesses, reduce lung function and initiate and exacerbate asthma, especially in children.[1–4] One reason is the long periods of time that children spend indoors.[5]

In 1992, Hasselblad *et al.*[2] carried out a meta-analysis including 11 studies, which concluded that children exposed to a long-term increase of 15 ppb NO_2 indoors suffer a 20% increase in respiratory

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illness risk. This early quantitative analysis became a benchmark study for the relationship between indoor NO_2 and respiratory illness in children, and an important reference for the outdoor NO_2 Air Quality Guideline value established by the World Health Organization (WHO) in 1997[6] and confirmed in 2005.[7] More recently, WHO has reviewed studies on indoor NO_2 exposure, but without doing a formal meta-analysis.[8] Recent journal reviews of the issue[1,4,9–11] have also been qualitative. In view of the dearth of quantitative meta-analyses based on recent studies, we decided to review studies on asthma, wheeze, gas cooking and indoor NO_2 in children with the purpose of obtaining quantitative effect estimates.

Methods

Selection criteria

We searched for studies from which quantitative effect estimates of the relationship between gas cooking, indoor NO_2 and respiratory health effects in children could be obtained. We attempted to identify all population studies in relation to this topic. The literature was searched with PubMed and ISI Web of Knowledge from 1977 up to 31 March 2013 with the following search terms: (i) indoor nitrogen dioxide and children; (ii) personal nitrogen dioxide and children; (iii) gas cooking and children; (iv) gas appliance and children; (v) unvented and children; (vi) gas heating and children; and (vii) gas heater and children. The seven search results were combined with the Boolean operator 'or'. All of the 34 epidemiological studies included in Table 5.2 of the recent WHO guidelines for indoor air quality and citations from previous reviews and identified articles were considered as well. Duplications were removed.

To be eligible for inclusion, studies had to: (i) be published in English; (ii) be primary study, not reviews; (iii) examine respiratory disease in infancy or in childhood (defined by a maximum age of subjects $\leqslant$18 years) as outcomes; (iv) examine exposure to indoor NO_2 or household gas cooking or gas heating; (v) be conducted within family houses, not in schools or classrooms; and (vi) report an odds ratio or other effect estimator[12] or sufficient data to estimate them. Articles fulfilling all six criteria were included for further review (Figure 1).

All studies were reviewed according to the six inclusion criteria. Commentaries, and studies not performed in children or exposures not relevant or without respiratory outcomes, were excluded. The remaining articles were reviewed independently by the three authors. Articles that did not report on the association between selected exposure variables and

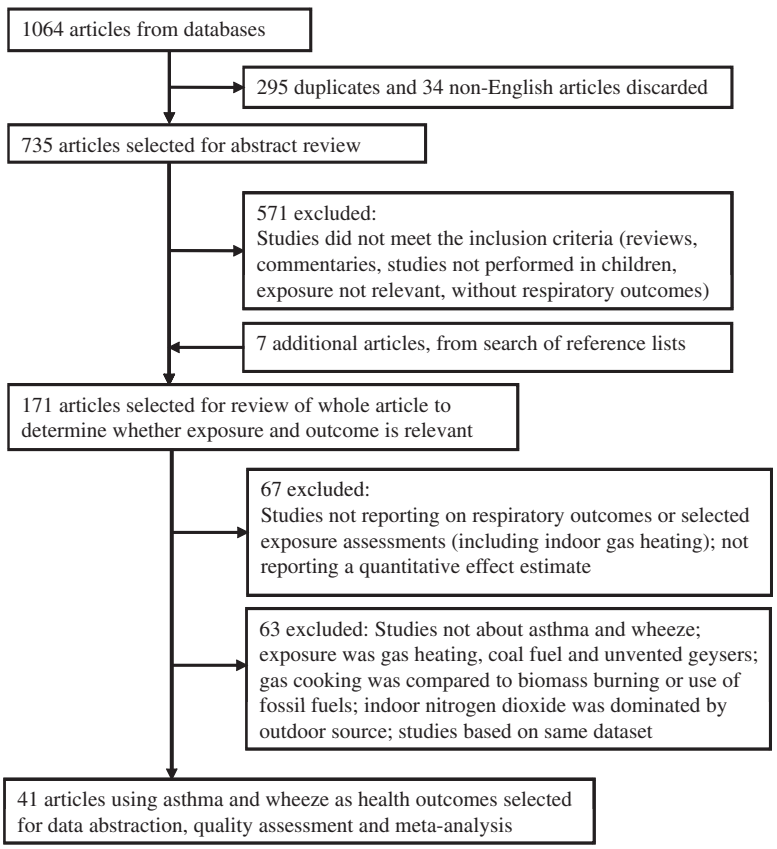

Figure 1 Study selection flow chart

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respiratory outcomes in children, that could not isolate indoor gas appliances from other combustion/energy sources (that is studies where gas, coal, wood, kerosene or fireplace cooking/heating were combined into one exposure group), that compared gas cooking with biomass burning or use of fossil fuels and that included indoor and/or personal NO_2 concentrations that were mainly affected by outdoor pollution from traffic (that is studies with personal monitoring of NO_2 where the sampling period covered both indoor and outdoor activities; and studies with indoor NO_2 measurements, in the absence of indoor sources, i.e. studies in populations with low prevalence (<10%) of gas stoves) were excluded (Figure 1).

Respiratory outcome selection

The respiratory outcomes of the studies that met the inclusion criteria included various symptoms such as rhinitis, phlegm, cough, chest illnesses, asthma and wheeze as well as lung function parameters. We restricted our review to the respiratory outcomes of wheeze and asthma, the two outcomes most frequently used in epidemiological studies among children. Both self-reported and doctor-diagnosed (either from self-reported questionnaire or clinical evaluation) asthma and self-reported wheeze were selected, in spite of the fact that the precise definition of such assessments might have some variability between studies. Furthermore, according to the occurrence time of asthma and wheeze, we categorized them into 'current asthma', 'lifetime asthma', 'current wheeze' and 'lifetime wheeze' to overcome the dilemma of various definitions of those health outcomes. 'Current' was defined as having incident asthma (or wheeze) with the symptoms occurring within the 12 months prior to the questionnaire. 'Lifetime asthma' was defined as ever having been diagnosed with asthma by a doctor; 'lifetime wheeze' was defined as wheeze ever. If studies defined wheeze in more than one way,[13] we selected wheeze without colds to avoid inclusion of symptoms related primarily to respiratory infections. We acknowledge that respiratory infections could be an interesting outcome by themselves.

Data abstraction

Studies on gas heating often lacked information on whether the heater was directly vented to the outside, in which case it would not be a source of indoor air pollution. For this reason, we did not include gas heating[14–19] in the meta-analysis; indoor NO_2 and gas cooking were the exposure variables that we focused on.

Ideally, meta-analysis would combine estimates only from studies with exactly the same exposure variables; we included studies for meta-analysis that were as similar as practicable with respect to these. One study about unvented kitchen geysers[20] was excluded because the reference category included gas cooking. One study[21] that compared the risk effect of gas cooking vs other cooking fuels was excluded because it compared two sources of combustion products. One study[22] that did not distinguish gas cooking from coal cooking was excluded. The concentrations of indoor NO_2 in some studies[23–26] were clearly dominated by traffic outdoors, because the percentage of study homes with household gas stoves was small; we excluded those studies as well. One panel study[27] was not included as this study provided insight only into the short-term exposure and its health effects. Two publications by Garrett *et al.*[28,29] were based on the same study population and data except for different confounder adjustment; we only included one study.[29] In this review, we refer to each population as a separate study and used the corresponding effect estimates; thus we excluded the combined risk estimates from Moshammer *et al.*[30] because we had already included the individual studies on which this paper was based. The study by von Maffei[31] was excluded because it was unclear whether it was current or lifetime asthma. In the end, 41 studies were selected for further analysis.

Selected articles were appraised using a data extraction form. Information on authors, publication year, country of origin, study design, population characteristics (gender and age), exposure definition (including proportion of gas cooking), definitions of respiratory outcomes in each reviewed article and the meta-analysis, risk measure and confounding factors was extracted.

If unadjusted and adjusted results were both reported, we extracted the one adjusted for potential confounding factors. Where more than one adjusted result was presented, we chose the one with adjustment of smoking in the family.[32] When a study reported only the number of cases and controls among the exposed and unexposed, we calculated the crude odds ratio and its corresponding 95% confidence interval (CI) following.[12] When a multi-city study provided risk estimates for single cities in addition to a combined estimate, we selected the combined estimates. If there were no combined estimates, risk estimates for single cities were used. If more than one follow-up analysis had been reported for the same population, we used results where health outcomes and exposure were measured in the same period[33–35] [e.g. questionnaire and indoor NO_2 measured in the same year; results linking childhood (adolescent) exposure to childhood (adolescent) health outcomes]. If results were presented separately for different locations of indoor NO_2 (kitchen, living room and bedroom), we extracted the results from living room, which were most frequently reported in other studies.[36] In Hoek *et al.*'s[36] study, we assumed that the majority of NO_2 concentration was in the range of 10–100 $\mu g/m^3$, based on the data that the geometric mean of NO_2 in the living room was 68.4 $\mu g/m^3$, and recalculated the effect estimates. The 95% confidence intervals were either extracted directly from the original articles or calculated by standard error transformation.

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Statistical methods

We conducted meta-analyses to obtain summary risk estimates for the association between asthma, wheeze and household NO_2 exposure and its surrogate, gas cooking. For every single exposure variable, to distinguish the differing reporting times of symptoms between studies, we reported not only the overall meta-OR combining all the studies but also the subgroup meta-ORs in both 'current' and 'lifetime' asthma (or wheeze). When a study reported risk estimates for different strata of the population, e.g. for boys and girls,[34,37–39] children with asthmatic mothers or non-asthmatic mothers[40] and children living in single- or multi-family houses,[41] we included these directly into the meta-analysis without combining them first. The risk estimates for the exposure ves non-exposure categories of gas cooking were summarized.

For NO_2 exposure, we calculated two types of pooled risk estimates: (i) for the comparison of asthma and wheeze risk at high vs low exposure independently of the exact definition of high and low exposure, and (ii) for asthma and wheeze risk per 15-ppb increase in continuous NO_2 concentration. For inclusion in the meta-analysis, we converted all results in $\mu g/m^3$ to 15 ppb using standard pressure and temperature. In the high vs low exposure meta-analysis, the included studies reported different specific ranges for NO_2, which precludes a direct comparison of effect estimates from these studies. Some studies categorized NO_2 levels into more than two categories; from these, we selected ORs for the highest compared with the lowest exposure category. We appreciate that this analysis is semi-quantitative.

Heterogeneity

We used standard chi-square tests to examine the heterogeneity among studies; results were defined as heterogeneous for $P < 0.10$.[42] The I^2 statistic was used to quantify the extent of inconsistency among the studies. The I^2 values <25% reflect low inconsistency, values of 25–75% reflect moderate inconsistency, whereas values >75% indicate high inconsistencies among studies.[43] Due to the heterogeneity among studies which were performed independently by different researchers in different populations, pooled risk estimates were calculated by random-effect models with inverse-variance weights.[44] Summary estimates from fixed-effect models were also presented in the Forest plots for comparison.

Influence analysis

To evaluate the influence of individual studies on the summary effect estimate, we performed influence analysis. This method recalculated the summary estimate, omitting one study at a time.

Sensitivity analysis

Sensitivity analyses were employed to test whether the risk estimates varied by study region and age of the participants. Age was categorized into ⩽6 years, 6–10 years and >10 years. Further subdivision of the youngest category was not possible because of the number of studies performed within that age range. Study regions were divided into Europe, North America, and Asian and Pacific area.

We noticed that the proportion of gas cooking varied considerably between studies. In order to examine whether observed exposure health relationships of a study were associated with the percentage exposed to gas cooking, stratified analyses were performed using 30% of cooking with gas stoves as a cut-off.

In our database, there were some studies which were conducted a long time ago. Since then, the actual use and the emissions of gas cookers as well as disease management strategies may have changed. To examine the influence of older studies, we compared risk estimates between older and newer studies as part of a sensitivity analysis. For operational purposes, the publication year 2000 was used as the cut-off.

Subsequently, exploratory univariate meta-regressions were performed to assess whether heterogeneity in associations between gas cooking and asthma and wheeze between studies was related to age of the participants, study region, proportion of gas cooking and year of publication.

Furthermore, random effects models were performed to determine the potential impact by asthmatic subjects. Asthmatic children may be more sensitive to the effects of indoor NO_2. Therefore, we repeated analyses of the associations of gas cooking and indoor NO_2 with wheeze by excluding two studies which focused on asthmatic children only at the initial recruitment.

Assessing publication bias

Publication bias was evaluated with funnel plots and the Egger's and Begg's tests.[45]

All statistical analyses were performed using STATA (version 10; StataCorp LP, College Station, TX, USA), employing the 'metan', 'metabias' and 'metainf' commands for meta-analyses and bias evaluation. 'Metareg' was used to test differences in effect size between subgroups of studies.

Results

A flow chart of the selection stages of the studies for analysis is shown in Figure 1. We extracted data from 41 studies published since 1977 assessing the relationship between household NO_2 or gas cooking and asthma and wheeze (Supplementary Table 1, available as Supplementary data at IJE online).[13,29,32–41,46–74] Among those 41 studies, 19 studies were conducted in Europe (UK, Austria, Germany, Netherlands, Czech Republic, Spain and Russia), 14 in North America (USA and Canada), 3 in Asia (China and Japan), 4 in Australia and 1 in New Zealand. Among them, four studies contributed information on infants[32,40,65,75]

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and two studies on asthmatic children;[41,46] the rest were studies on general populations of school-age children. There were 16 cross-sectional, 18 cohort, and 7 case-control studies. However, most of the reports from cohort studies were based on cross-sectional rather than longitudinal analysis. Three studies included the association between previous gas cooking exposure and the development of respiratory symptoms: De Bilderling *et al.*[33] and Ponsonby *et al.*[32] used a cohort design to link early exposure estimates to subsequent risk of wheeze and asthma, and Wong *et al.*[35] used a survey study with a retrospective questionnaire. The other reviewed studies focused mainly on whether the presence of respiratory symptoms was associated with current exposure

The meta-analysis of findings from 19 studies on the association between gas cooking and asthma (Figure 2) demonstrates an increased odds of current asthma [random effects meta-odds ratio (OR) 1.42; 95% CI, 1.23–1.64, $P=0.000$, $n=11$ studies) and lifetime asthma (1.24; 95% CI, 1.04–1.47, $P=0.014$, $n=8$ studies) in children exposed to gas cooking. The overall odds ratio was 1.32 (95% CI, 1.18–1.48, $P=0.000$; $I^2=19.8\%$, heterogeneity P-value $=0.204$) for the association between asthma and gas cooking (Figure 2a) and 1.09 (95% CI, 0.91–1.31, $I^2=35.5\%$, heterogeneity P-value $=0.185$) per 15-ppb increase in NO_2 exposure (Figure 2b). Indoor NO_2 was positively associated with the odds of current wheeze (random effects meta-OR 1.15 per 15 ppb, 95% CI, 1.06–1.25, $P=0.001$) (Figure 3b). There was only one study reporting lifetime wheeze in children exposed to indoor NO_2; combining it into the meta-analysis yielded a pooled random effects OR of 1.12 (95% CI, 1.04–1.21, $P=0.002$, $I^2=11.3\%$, heterogeneity P-value $=0.337$). The combined analysis of 28 studies, including >11 000 children with wheeze, demonstrated no increased risk in children who had ever been exposed to gas cooking (random effects meta-OR $=1.06$, 95% CI, 0.99–1.13, $I^2=42.8\%$, heterogeneity P-value $=0.006$) (Figure 3a). Results for current wheeze (random effects meta-OR $=1.07$, 95% CI, 0.99–1.15, heterogeneity P-value $=0.002$) were similar to results for all wheeze. We observed heterogeneity among those studies, with I^2 of 50.4% and 42.8% for current and all wheeze, respectively. Therefore, the combined estimates for lifetime wheeze based on the random effects model were likely to represent the effect more accurately. The Forest plots ordered by publication date (Figures 2 and 3) show that there was no obvious trend in risk estimates over time. An influence analysis showed that no single study dominated the combined estimates.

Four of the 41 studies compared children exposed to high $NO_2$with children exposed to low NO_2.[49,53,65,69] We did not find an increase in asthma[49,53] (random effects meta-OR $=1.10$, 95% CI, 0.35–3.40, $I^2=49.5\%$, heterogeneity P-value $=0.159$) and in wheeze[53,65,69] (random effects meta-OR $=0.81$, 95% CI, 0.59–1.12, $I^2=0.0\%$, heterogeneity P-value $=0.715$) among children with the highest compared with the lowest NO_2 exposure. The results, however, should be interpreted with caution because the number of studies included was small.

We performed additional analyses to examine the pooled estimates for wheeze when restricted to general populations of children, excluding studies based on asthmatic children.[41,46] Restricting the analysis to general populations of children did not change the effect estimates (Table 1). When we excluded crude effect estimates from five studies[38,39,52,59,68] without confounder adjustment, the summary effect of gas cooking exposure on asthma in children became somewhat stronger (Table 1).

Risk estimates for asthma were not different in children aged $\leqslant 6$ years,[32,52,60,70,72] 6–10 years[37,49–51,58,59,64] or >10 years[29,39,54,56,57,66,68] (Table 2). Stratification by study region showed that the ORs for the association of all asthma with gas cooking exposure tended to be higher in Europe (random effects meta-OR $=1.34$, 95% CI, 1.15–1.57) and the Asian-Pacific region (random effects meta-OR $=1.29$, 95% CI,1.15–1.45), and lower in North America (random effects meta-OR $=1.12$, 95% CI, 0.73–1.73). However, the ORs did not differ significantly between regions. The trend was similar for all wheeze (Table 3).Taking the proportion of participants using gas for cooking into account (Table 2), there was a tendency for the risk estimates to be higher in the studies which had less than 30% of participants using gas cooking. No stratified analyses by age, study region, proportion of gas stoves or year of publication were performed for indoor NO_2 as the numbers of studies in the different strata were too small to obtain enough statistical power.

Almost half of the included studies were published before 2000. The estimated effects of gas cooking on asthma were higher in studies that were published before the year 2000; however, the estimates did not differ in the strata of published year ($P>0.05$) (Table 2).

Results of stratified analyses and meta-regressions for current asthma, lifetime asthma, current wheeze and lifetime wheeze are also presented in Tables 2 and 3.

The funnel plots (Supplementary Figure 1, available as Supplementary data at *IJE* online) and P-values from Begg's ($P_{asthma}=0.971$, $P_{wheeze}=0.975$) and Egger's ($P_{asthma}=0.890$, $P_{wheeze}=0.644$) tests provided no evidence of publication bias.

Discussion

Our meta-analyses suggest that children living in a home with gas cooking have a 42% increased risk of having current asthma, a 24% increased risk of lifetime asthma and an overall 32% increased risk of

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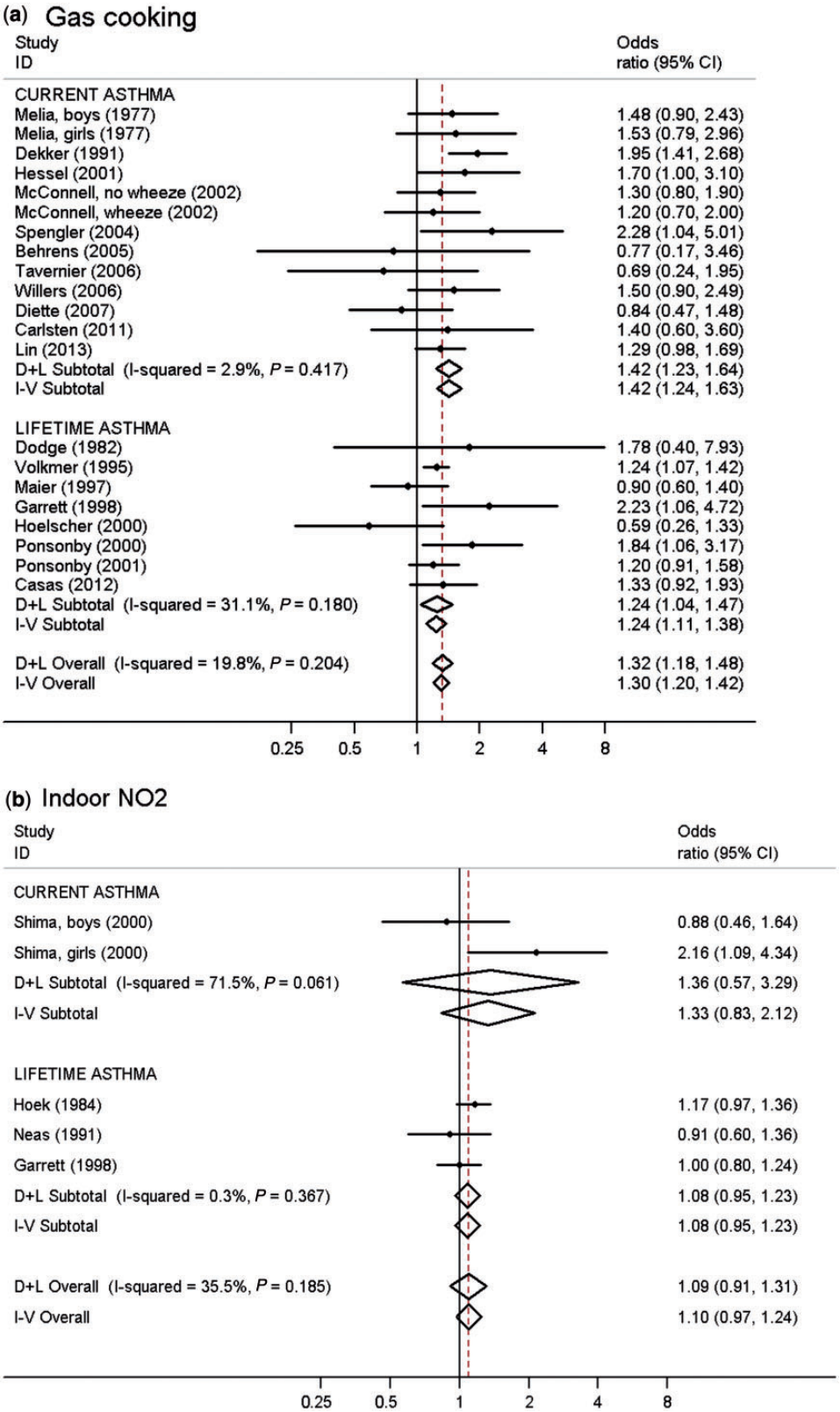

Figure 2 Meta-analysis of studies assessing association between asthma (current/lifetime) and gas cooking (a) or indoor NO_2, (b) in children. The odds ratio for each study is indicated by a black dot, and the horizontal line shows the corresponding 95% CI. The combined estimate is indicated by the diamond-shaped box. D + L Subtotal/Overall = random effect meta-analysis; I-V Subtotal/Overall = fixed effects meta-analysis

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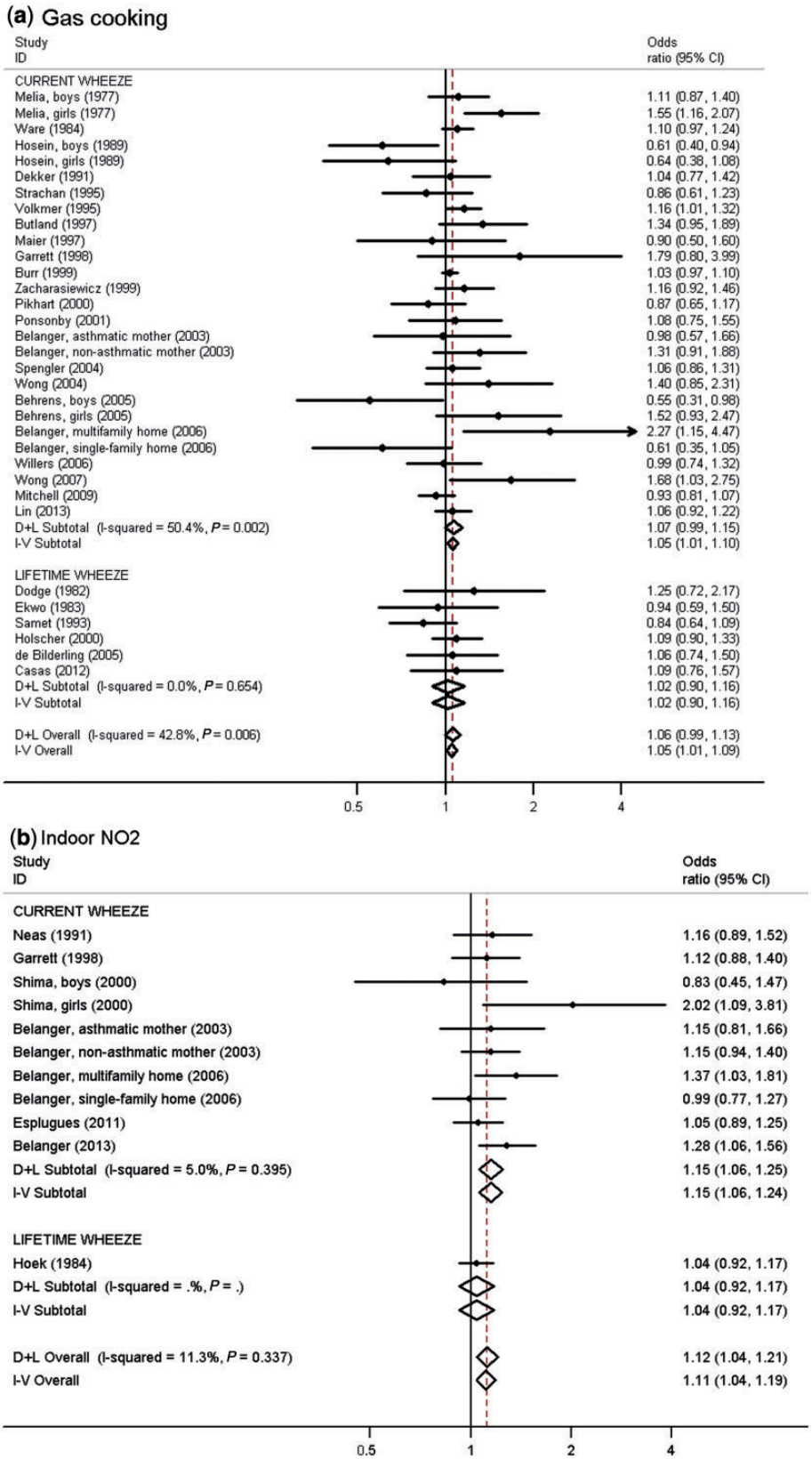

Figure 3 Meta-analysis of studies assessing association between wheeze (current/lifetime) and gas cooking (a) or indoor NO_2, (b) in children. The odds ratio for each study is indicated by a black dot, and the horizontal line shows the corresponding 95% CI. The combined estimate is indicated by the diamond-shaped box. D + L Subtotal/Overall = random effects meta-analysis; I-V Subtotal/Overall = fixed effects meta-analysis

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Table 1 Meta-analysis results of studies restricted to unselected children and of studies with confounder adjustment

Variable	Number of studies included	Summary odds ratio (95% CI)	I^2 (heterogeneity *P*-value)
Unselected children[a]			
Gas cooking			
Current wheeze	21	1.06 (1.01–1.10)	45.1% (0.008)
All wheeze[b]	27	1.05 (1.01–1.09)	36.5% (0.024)
Indoor NO_2[a]			
Current wheeze	5	1.12 (1.01–1.23)	0.0% (0.530)
All wheeze[b]	6	1.09 (1.01–1.17)	0.0% (0.547)
Studies with confounder adjustment			
Asthma			
Gas cooking			
Current asthma	8	1.49 (1.28–1.73)	0.0% (0.548)
Lifetime asthma	7	1.29 (1.09–1.52)	23.6% (0.249)
All asthma [b]	15	1.37 (1.22–1.53)	14.4% (0.288)
Indoor NO_2			
Current asthma	1	1.36 (0.57–3.29)	–
Lifetime asthma	3	1.08 (0.95–1.23)	0.0% (0.367)
All asthma [b]	4	1.09 (0.91–1.31)	35.5% (0.185)
Wheeze			
Gas cooking			
Current wheeze	19	1.05 (1.01–1.10)	40.6% (0.026)
Lifetime wheeze	6	1.02 (0.90–1.16)	0.0% (0.654)
All wheeze[b]	25	1.05 (1.01–1.09)	30.5% (0.065)
Indoor NO_2			
Current wheeze	7	1.15 (1.06–1.24)	5.0% (0.395)
Lifetime wheeze	1	1.04 (0.92–1.17)	–
All wheeze[b]	8	1.11 (1.04–1.19)	11.3% (0.337)

[a]Without two studies performed in asthmatics only [Belanger *et al.* 2006 (gas cooking) and Belanger *et al.* 2013 (NO_2)]. The health outcome in these two studies was 'current wheeze'. Results for 'lifetime wheeze' are the same as in Figure 3, as all studies were performed in unselected children and are therefore not presented here.
[b]Current + lifetime.
[c]Per 15-ppb increase in NO_2.

having current and lifetime asthma; per 15 ppb increase in indoor NO_2 level, children have a 15% increased risk of having current wheeze. The meta-analyses found no increase in the risk of asthma in relation to indoor NO_2 exposure and no increase in the risk of wheeze in relation to gas cooking exposure. The risk estimates for asthma were somewhat higher in studies which had <30% of participants using gas cooking compared with those ⩾30%. The results did not vary much between age groups (⩽6 years, 6–10 years and >10 years) or among regions (Europe, Asian-Pacific region and North America). There was no indication of publication bias when considering all the evidence.

The present study extends the previous meta-analysis of indoor NO_2 by Hasselblad *et al.*[2] which reported that indoor NO_2 increased lower respiratory tract illnesses (LRI) by 18% (OR = 1.18, 95% CI, 1.11–1.25) in children for each 15-ppb increase in indoor NO_2. The LRI definitions used in the reviewed studies in the Hasselblad meta-analysis[2] often included relatively minor symptoms probably related to transient respiratory tract infections. The results of this and our study are therefore not directly comparable. Our meta-analysis did not focus on LRI but on asthma and wheeze (without colds), included data from only those studies with gas cooking without other combustion sources as exposure variable, and indoor NO_2 only when dominated by indoor sources. The definitions of 'asthma' and 'wheeze' differed in various studies; we categorized them into current and lifetime symptoms to standardize the

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Table 2 Random effects meta-analysis and univariate meta-regression of studies on gas cooking and asthma stratified by age, study region, proportion of gas cooking and year of publication

	Number of studies	Summary odds ratio (95% CI)	I^2 (heterogeneity *P*-value)	Ratio of odds ratios (95% CI)[a]
Current asthma				
Age of participants				
⩽6years	3	1.22 (0.95–1.56)	0.0% (0.504)	1.00 (ref)
6–10 years	4	1.51 (1.12–2.02)	33.5% (0.211)	1.25 (0.82–1.90)
>10 years	4	1.54 (1.16–2.06)	0.0% (0.500)	1.27 (0.80–2.03)
Study region				
Europe	7	1.34 (1.13–1.60)	0.0% (0.666)	1.00 (ref)
North America	3	1.36 (0.76–2.43)	68.7% (0.041)	1.13 (0.74–1.71)
Asia-Pacific	1	1.50 (1.01–2.23)	0.0% (0.937)	1.11 (0.65–1.89)
Proportion of gas cooking[b]				
<30%	4	1.79 (1.38–2.33)	0.0% (0.615)	1.00 (ref)
⩾30%	6	1.32 (1.12–1.56)	0.0% (0.655)	0.74 (0.52–1.05)
Publication year				
Before 2000	2	1.76 (1.37–2.25)	0.0% (0.597)	1.00 (ref)
2000 or later	9	1.30 (1.10–1.53)	0.0% (0.601)	0.74 (0.53–1.03)
Lifetime asthma				
Age of participants				
⩽6years	2	1.38 (0.98–1.94)	0.0% (0.506)	1.00 (ref)
6–10 years	3	1.16 (0.95–1.41)	0.0% (0.375)	0.83 (0.41–1.67)
>10 years	3	1.28 (0.50–3.29)	65.3% (0.056)	0.92 (0.33–2.53)
Study region				
Europe	1	1.33 (0.92–1.93)	–	1.00 (ref)
North America	3	0.86 (0.60–1.24)	0.0% (0.412)	0.65 (0.31–1.37)
Asia-Pacific	4	1.32 (1.10–1.59)	28.7% (0.240)	0.96 (0.55–1.68)
Proportion of gas cooking[b]				
<30%	3	1.27 (0.87–1.84)	53.8% (0.115)	1.00 (ref)
⩾30%	3	1.07 (0.65–1.76)	10.4% (0.188)	0.98 (0.62–1.53)
Year of publication				
Before 2000	4	1.24 (0.93–1.65)	37.2% (0.189)	1.00 (ref)
2000 or later	3	1.25 (0.93–1.68)	44.0% (0.148)	1.02 (0.68–1.54)
All asthma[c]				
Age of participants				
⩽6 years	5	1.26 (1.12–1.42)	0.0% (0.506)	1.00 (ref)
6–10 years	7	1.31 (1.08–1.59)	38.8% (0.133)	1.03 (0.79–1.35)
>10 years	7	1.45 (1.07–1.97)	26.6% (0.217)	1.27 (1.05–1.54)
Study region				
Europe	8	1.34 (1.15–1.57)	0.0% (0.763)	1.00 (ref)
North America	6	1.12 (0.73–1.73)	66.7% (0.010)	0.92 (0.69–1.23)
Asian–Pacific	5	1.29 (1.15–1.45)	0.0% (0.442)	1.01 (0.76–1.35)
Proportion of gas cooking[b]				
<30%	7	1.45 (1.12–1.87)	40.1% (0.124)	1.00 (ref)
⩾30%	10	1.25 (1.13–1.38)	0.0% (0.617)	0.86 (0.68–1.06)
Publication year				
Before 2000	6	1.42 (1.13–1.80)	50.0% (0.062)	1.00 (ref)
2000 or later	13	1.28 (1.13–1.45)	0.0% (0.467)	0.93 (0.75–1.16)

[a]Ratios of odds ratios are the odds ratio from studies with the characteristic divided by the odds ratios from studies of the reference category and were calculated from coefficients of meta-regression b as exp(b). Ratios above 1.0 indicate a larger odds ratio for studies with the characteristic.
[b]Information of proportion of gas cooking was not available in two studies (Garrett *et al.* 1998; Tavernier *et al*. 2005). Belanger *et al.* (2006) was counted twice in this analysis as results were presented for multi-family and single-family homes separately, and proportions for gas cooking were ⩾30% for multi-family homes and <30% for single-family homes, respectively.
[c]Current + lifetime.

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Table 3 Random effects meta-analysis and univariate meta-regression of studies on gas cooking and wheeze stratified by age, study region, proportion of gas cooking and year of publication

	Number of studies	Summary odds ratio (95% CI)	I^2 (heterogeneity *P*-value)	Ratio of odds ratios (95% CI)[a]
Current wheeze				
Age of participants				
⩽6 years	4	1.16 (1.03–1.30)	3.7% (0.386)	1.00 (ref)
6–10 years	11	1.05 (0.96–1.15)	32.6% (0.129)	0.90 (0.70–1.17)
>10 years	7	1.02 (0.86–1.21)	68.5% (0.001)	0.88 (0.67–1.16)
Study region				
Europe	9	1.07 (0.97–1.18)	48.7% (0.035)	1.00 (ref)
North America	6	0.96 (0.78–1.19)	61.3% (0.008)	0.92 (0.72–1.18)
Asia-Pacific	7	1.14 (0.99–1.31)	47.9% (0.074)	1.08 (0.85–1.37)
Proportion of gas cooking				
<30%	4	0.91 (0.73–1.14)	49.4% (0.079)	1.00 (ref)
⩾30%	15	1.09 (1.01–1.18)	49.2% (0.008)	1.16 (0.95–1.42)
Publication year				
Before 2000	11	1.08 (0.98–1.19)	52.5% (0.014)	1.00 (ref)
2000 or later	11	1.06 (0.93–1.20)	50.7% (0.015)	0.96 (0.81–1.14)
Lifetime wheeze				
Age of participants				
⩽6 years	1	0.84 (0.64–1.10)	–	1.00 (ref)
6–10 years	1	1.09 (0.76–1.67)	–	1.30 (0.62–2.69)
>10 years	4	1.08 (0.92–1.26)	0.0% (0.890)	1.28 (0.78–2.12)
Study region				
Europe	3	1.08 (0.93–1.27)	0.0% (0.990)	1.00 (ref)
North America	3	0.91 (0.74–1.13)	0.0% (0.441)	0.84 (0.58–1.22)
Asia-Pacific	0	-	-	-
Proportion of gas cooking[b]				
<30%	1	1.09 (0.76–1.57)	-	1.00 (ref)
⩾30%	4	1.08 (0.92–1.26)	0.0% (0.890)	0.99 (0.52–1.88)
Publication year				
Before 2000	3	0.91 (0.74–1.13)	0.0% (0.441)	1.00 (ref)
2000 or later	3	1.08 (0.93–1.27)	0.0% (0.990)	1.19 (0.82–1.73)
All wheeze[c]				
Age of participants				
⩽6 years	5	1.10 (0.93–1.29)	44.3% (0.110)	1.00 (ref)
6–10 years	12	1.05 (0.97–1.15)	26.7% (0.175)	0.96 (0.78–1.18)
>10 years	11	1.04 (0.92–1.17)	55.8% (0.006)	0.95 (0.77–1.18)
Study region				
Europe	12	1.07 (0.99–1.15)	34.0% (0.103)	1.00 (ref)
North America	9	0.97 (0.82–1.13)	53.2% (0.015)	0.92 (0.77–1.10)
Asia-Pacific	7	1.14 (0.99–1.31)	47.9% (0.074)	1.06 (0.88–1.27)
Proportion of gas cooking[b]				
<30%	6	0.94 (0.78–1.14)	43.0% (0.104)	1.00 (ref)
⩾30%	20	1.09 (1.01–1.16)	39.1% (0.030)	1.14 (0.96–1.34)
Publication year				
Before 2000	14	1.06 (0.97–1.16)	48.1% (0.017)	1.00 (ref)
2000 or later	14	1.06 (0.96–1.17)	40.3% (0.044)	0.98 (0.86–1.13)

[a]Ratios of odds ratios are ratios of the odds ratio from studies with the characteristic divided by the odds ratio from studies of the reference category and were calculated from coefficients of meta-regression b as exp(b). Ratios above 1.0 indicate a larger odds ratio for studies with the characteristic.
[b]Information on proportion of gas cooking was unavailable in three studies (Garrett *et al.* 1998; Samet *et al.* 1993; Zacharasiewicz *et al.* 1999).
[c]All (current + lifetime).

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health effects and thus to reduce the heterogeneity between studies.

Although asthma and wheeze are associated, they present distinct entities. In a Dutch birth cohort study, for example, it was found that only 11% of children with symptoms suggestive of asthma, including wheeze, at preschool age had asthma at age 7–8 years.[76] Moreover, one-time wheeze was sufficient to characterize a child as having wheezed in many of the studies included in the meta-analysis and typically no distinction was made between wheeze with and without respiratory infections. This may explain why our meta-analysis revealed stronger associations with gas cooking for asthma compared with wheeze.

Gas cooking produces NO_2 and other pollutants such as ultrafine particles. Our finding of an association between gas cooking and asthma in the absence of an association between measured NO_2 and asthma suggests that gas cooking may act as a surrogate for causal variables other than air pollutants produced by gas combustion. This is supported by an Australian study, where the association between gas cooking and respiratory symptoms remained significant after adjustment for measured NO_2.[29] Residual confounding by (unmeasured) factors that are associated with gas cooking might be another explanation for our finding of an association between asthma and gas cooking, but not with indoor NO_2. However, this is not very likely as we used effect estimates from the included studies which were almost always adjusted for known determinants of childhood asthma. It is also possible that no relationship between indoor NO_2 and asthma was found because there were fewer studies that had direct NO_2 measurements, and study populations were usually smaller in these studies. Point estimates for the association of NO_2 and gas cooking with current asthma were actually very similar to those for gas cooking and asthma, but confidence intervals were wider for NO_2. As gas cooking is a strong determinant of indoor NO_2, it has been argued that one is actually more likely to find associations with gas cooking than with NO_2 because much larger studies can be (and have been) conducted using the surrogate exposure variable.[77]

Heterogeneity among reviewed studies existed in various factors such as stove type, age of population, size of population exposed to gas cooking, susceptibility of study population, study region, study design, sampling season, other indoor factors and diagnosis of asthma and wheeze. We therefore conducted meta-regression to explore whether the heterogeneity could be explained by age, study region, study design or size of the population exposed to gas cooking. None of these factors appeared to be associated with the magnitude of the effect estimates extracted from the study papers. We did note that the association between gas cooking and asthma was somewhat stronger in studies published before the year 2000 than in later studies. Possibly, gas cooking in newer studies is associated with lower indoor pollution levels because of the introduction of microwaves displacing some of the meal preparation, changes in stove performance or kitchen ventilation etc.[53,72] Exposure assessment (questionnaire reports of gas cookers and passive measurements of NO_2) and statistical analysis (mostly logistic regression) were mostly rather straightforward and, therefore, they do not seem a likely source of heterogeneity between the reviewed studies.

The findings of our meta-analysis on asthma were also not different when we excluded studies where less than 30% of the population used gas for cooking, by restricting the study population to general population of children, and by excluding studies without adjustment for potential confounders. The exclusion of single studies from the analysis did not change the pooled estimates. Also, *P*-values from the Egger's and Begg's tests, as well as the absence of funnel plot asymmetry, suggested that no publication bias exists in our results.

Our analysis was based on observational studies and we cannot exclude that associations between gas cooking and asthma are in part due to information bias, e.g. because parents may suspect risks are associated with gas cooking. However, with studies coming from so many different settings, we do not think this is a likely explanation for the observed associations.

Although the effects of gas cooking and indoor NO_2 on asthma and wheeze were found to be relatively small (all random-effects meta-odds ratios were less than 1.5) the public health impact may still be considerable because gas cooking is widespread. A recent large population study found that 60–70% of European children lived in gas-cooking homes.[78] It is not clear to what extent the observed associations with gas cooking are attributable to NO_2 alone or also to other pollutants associated with the use of gas for cooking. In outdoor air pollution studies, NO_2 often is used as a marker of a complex, traffic-related air pollution mixture, which makes extrapolation of our results to outdoor air pollution difficult. Indoors, gas cookers can be replaced by electric cookers, and gas cooking fumes can be removed by using ventilation hoods.

Conclusion

In summary, this meta-analysis provides quantitative evidence that gas cooking increases the risk of asthma in children, and indoor NO_2 increases the risk of current wheeze in children.

Funding

W.L. was supported by a research fellowship of the Institute for Risk Assessment Sciences (IRAS) Foundation.

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Acknowledgements

All authors had full access to all the data and take responsibility for the integrity of the data, the accuracy of the data analysis and the accuracy and completeness of references. W.L., U.G. and B.B. conducted the literature search independently and decided on inclusion of studies. Discrepancies among the authors were discussed and adjudicated. W.L. and U.G. extracted the data. W.L. did the statistical analyses and wrote the manuscript. U.G. and B.B. critically reviewed the manuscript and provided important intellectual content.

Conflict of interest: None declared.

KEY MESSAGES

- The last meta-analysis of the respiratory health effects of indoor NO_2 exposure was published almost 20 years ago. The current paper provides an up-to-date review of the literature with childhood respiratory health data that used either indoor NO_2 or the use of gas for cooking as the exposure metric.
- Household gas cooking is associated with increased odds of current asthma and lifetime asthma in children. The risk of overall asthma in children with gas cooking exposure was 1.32 (95% confidence interval, 1.18–1.48).
- The risk of childhood current wheeze increases by 15% per 15-ppb increase in indoor NO_2 levels.

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Published by Oxford University Press on behalf of the International Epidemiological Association *International Journal of Epidemiology* 2013;**42**:1737–1739
doi:10.1093/ije/dyt189
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Commentary: Gas cooking and child respiratory health—time to identify the culprits?

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Accepted 19 August 2013

In this issue of the *IJE*, Lin and colleagues[1] report the results of a meta-analysis of the effect of indoor nitrogen dioxide (NO_2) and gas cooking on asthma and wheeze in children. Effect estimates summarizing 19 studies show that the risk of asthma increases by 32% when a gas cooker is present in the home, and 7 studies combined show that the risk of wheeze increases by 15% for a 15 ppb increase in NO_2. The presence of gas cookers inside the home is common in developed countries (around 50–70%) and has long been established as a main source of indoor air pollution, in particular NO_2.[2] Young children are among

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Kile et al. Environmental Health 2014, 13:71
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ENVIRONMENTAL HEALTH

RESEARCH Open Access

A cross-sectional study of the association between ventilation of gas stoves and chronic respiratory illness in U.S. children enrolled in NHANESIII

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Abstract

Background: Gas stoves emit pollutants that are respiratory irritants. U.S. children under age 6 who live in homes where gas stoves are used for cooking or heating have an increased risk of asthma, wheeze and reduced lung function. Yet few studies have examined whether using ventilation when operating gas stoves is associated with a decrease in the prevalence of respiratory illnesses in this population.

Methods: The Third National Health and Nutrition Examination Survey was used to identify U.S. children aged 2–16 years with information on respiratory outcomes (asthma, wheeze, and bronchitis) who lived in homes where gas stoves were used in the previous 12 months and whose parents provided information on ventilation. Logistic regression models evaluated the association between prevalent respiratory outcomes and ventilation in homes that used gas stoves for cooking and/or heating. Linear regression models assessed the association between spirometry measurements and ventilation use in children aged 8–16 years.

Results: The adjusted odds of asthma (Odds Ratio [OR] = 0.64; 95% confidence intervals [CI]: 0.43, 0.97), wheeze (OR = 0.60, 95% CI: 0.42, 0.86), and bronchitis (OR = 0.60, 95% CI: 0.37, 0.95) were lower among children whose parents reported using ventilation compared to children whose parents reported not using ventilation when operating gas stoves. One-second forced expiratory volume (FEV_1) and FEV_1/FVC ratio was also higher in girls who lived in households that used gas stoves with ventilation compared to households that used gas stoves without ventilation.

Conclusions: In homes that used gas stoves, children whose parents reported using ventilation when operating their stove had higher lung function and lower odds of asthma, wheeze, and bronchitis compared to homes that never used ventilation or did not have ventilation available after adjusting for other risk factors. Additional research on the efficacy of ventilation as an intervention for ameliorating respiratory symptoms in children with asthma is warranted.

Keywords: Asthma, Wheeze, Bronchitis, Gas stoves, Ventilation, Spirometry, NHANES, Children

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Background

Asthma is the most common chronic childhood disease and is characterized by recurrent airway obstruction, bronchial hyper-responsiveness, and airway inflammation [1]. It is also the leading cause of childhood hospitalizations and school absenteeism [2]. There is considerable evidence that air pollution - specifically coarse and fine particulate matter, ozone, sulfur dioxides, and nitrogen oxides - is associated with increased rates of asthma, asthma morbidity, respiratory illness and diminished lung function in children [3-8].

In the indoor environment, gas stoves are a common source of air pollution, including combustion-related particulate matter and nitrogen oxides [9-16]. While gas stoves are primarily used for cooking, approximately 7.7 million U.S. households (9.3%) reported using their gas stove or oven for heat at least once during the previous year [17]. There is considerable evidence from epidemiological studies in developed countries that gas stoves used for cooking and/or heat are associated with an increased risk of asthma and respiratory symptoms in children [9,18-33]. Although other studies that have examined the relationship between gas stoves or nitrogen dioxide levels in homes do not observe significant associations with asthma symptoms in childhood [34-36].

Housing characteristics have been shown to influence indoor air pollution levels. For instance, indoor air concentrations of nitrogen dioxide can be higher than ambient levels if there are unvented combustion appliances in the home, such as gas stoves [37]. Ventilation has also been shown to reduce the concentration of other indoor air pollutants such as formaldehyde and volatile organic compounds [38]. There are many different types of household ventilation systems, some of which are automatic, and some of which require point-of-use operation such as kitchen stove vent hoods. While several studies have examined the role of ventilation on indoor air pollutants and indoor air pollution on children's chronic respiratory illnesses, little is known about the role of behavior related to point-of-use ventilation and how this behavior might influence children's respiratory health [39-41]. Subsequently, we theorized that if gas stoves in homes and their emissions are related to asthma and its symptoms in children, then using ventilation when operating gas stoves should reduce indoor air pollution levels and benefit children's respiratory health outcomes. Specifically, we hypothesized that using ventilation when operating gas stoves should be associated with a lower prevalence of chronic respiratory illnesses in children.

Methods

Study population

The Third National Health and Nutrition Examination Survey (NHANES III) is a nationally representative cross-sectional survey of the civilian non-institutionalized U.S. population conducted by the National Center for Health Statistics from 1988–1994. Participants were administered standardized interviews in their homes and underwent physical examinations and laboratory testing in mobile examination centers [42]. NHANES III includes data on children's respiratory health, spirometry data and residential characteristics, which provide a unique opportunity to assess the relationship between parental habits when using gas stoves and respiratory illnesses in U.S. children.

To focus on the association between respiratory illnesses in children and parental use of ventilation in homes that had gas stoves in their kitchens, the current analysis was restricted to children aged 2–16 years (n = 12,570) whose parents: *i)* reported that a gas stove was used in the past twelve months in their child's primary residence (yes); *ii)* provided information on the presence of ventilation near the gas stove (yes/no) and their use of ventilation (never, rarely, sometimes, or always); *iii)* provided information on their child's respiratory health (doctor-diagnosed asthma [yes/no], doctor-diagnosed bronchitis [yes/no], and chest wheeze [yes/no]); and *iv)* reported their child's body mass index, parental history of asthma or hay fever (yes/no), presence of a pet in the household (yes/no), and history of smoking cigarettes indoors (yes/no). Twelve respondents did not answer the question about ventilation. Fewer participants consented to the examination portion of the survey where measurements were taken to compute body mass index. This resulted in data on 7,378, 7,380, and 7,378 children who resided in a home that had a gas stove in the kitchen and who provided information on asthma, wheeze, and chronic bronchitis respectively. Additionally, spirometry measurements were measured only in a subset of children ≥ 8 years old (N = 2,400). Details on deriving the sample size are provided in Additional file 1: Figure S1. Missing data was assumed to be completely at random.

NHANES III was approved by the National Center for Health Statistics Institutional Review Board. Participants who were 12 to 17 years old and their parents provided informed consent; participants who were 7 to 11 years old provided assent and their parents provided consent; and, parents provided informed consent for those <7 years old.

Behaviors when using gas stoves and ventilation characterization

Parents were asked, "Is there a gas stove or oven used to cook in this house (yes/no)." Only parents who answered "yes" were asked the follow up question about ventilation. Due to this skip pattern design in the NHANES III questionnaire, the analytical sample was restricted to children whose parents answered "yes" to the gas stove question. Children were classified as living in households

that used gas stoves for heat (yes/no) based on their parent's response to the question, "Was this gas stove or oven used to heat the house over the past 12 months (yes/no)".

Ventilation was characterized based on parent's response to, "Is there an exhaust fan near this stove that sends fumes outside the home (yes/no)" and, "How often is this exhaust fan used (never, rarely, sometimes, or always)." We classified children as living in a household that did not use ventilation if parents stated that there was no exhaust fan or that they never used the exhaust fan. We classified children as living in a household that used ventilation if parents reported that they rarely, sometimes or always used the exhaust fan.

Respiratory health outcomes

For children aged 2–16 years of age, dichotomous respiratory health outcomes were available including parent-reported: *i)* doctor-diagnosed asthma, *ii)* chest wheeze or whistling in past 12 months, and *iii)* doctor-diagnosed chronic bronchitis.

Lung function tests were performed at the mobile examination centers on children between 8–16 years of age following spirometry protocols issued by the American Thoracic Society [43].

Sociodemographic factors and covariates

Selected characteristics were assessed for their relationship to respiratory outcomes and parental behaviors regarding gas stoves. These included age group, sex, race-ethnicity, parental education, parental history of asthma or hay fever, body mass index percentile for age cut-offs following the U.S. Centers for Disease and Prevention recommended guidelines [44], poverty income ratio, household income < $20,000, cigarette smoking indoors, heating with a gas stove, the presence of pets in the household (only cats, dogs and birds), type of residence (rural versus urban) and US census region.

Statistical approach

To account for the complex sampling design, data were analyzed using appropriate NHANES sample weights using the "svy" command in Stata version 12.1 (StataCorp, College Station, TX). The weighted proportions of participants with respiratory health outcomes and 95% confidence intervals were calculated for children residing in four different settings in homes: (1) where parents reported using ventilation when operating gas stoves for cooking or heating; (2) where parents reported not using ventilation when operating a gas stove for cooking or heating; (3) where parents reported using ventilation when operating gas stoves for cooking only; and, (4) where parents reported not using ventilation when operating gas stoves for cooking only. Chi-squared tests assessed the association between prevalent respiratory health outcomes and ventilation use. Covariates were included in the models if they were associated with a respiratory health outcome at $\alpha < 0.20$. Additionally, household income below $20,000, which had the least amount of missing data, was included in each model because prior research has demonstrated a strong association between income and reported ventilation use.

Multivariate linear regression models assessed the association between percent of predicted spirometry measurements (one-second forced expiratory volume [FEV_1], forced vital capacity [FVC], and FEV_1/FVC ratio) and gas stoves in all children aged 8–16 years. These models were also stratified by sex. Reference population spirometry values were calculated using NHANES III race and sex specific estimating equations that accounted for age and height for FEV_1 and FVC, as derived by Hankinson et al. [45] and Collen et al. [46]. Percent-predicted values were calculated by taking the ratio of observed spirometry measurements over predicted values and multiplying by 100%. Model covariates accounted for environmental and host factors such as indoor cigarette smoking, the presence of pets in the home, household income < $20,000, using a gas stove for heating purposes, and asthma status.

Results

Population characteristics and prevalence rates of respiratory illnesses for children residing in homes that used a gas stove are presented in Table 1. Overall, the unadjusted prevalence of wheeze (14.2% vs. 19.3%, p-value = 0.01, N = 7,380) and bronchitis (3.2% vs. 5.0%, p-value = 0.02, N = 7,378) were lower among children residing in households that reported using ventilation when operating their gas stoves compared to households that did not use ventilation when operating their gas stove. The unadjusted prevalence of asthma (8.1% vs. 11.1%, p-value = 0.11, N = 7,378) was not significantly different between households by ventilation status. The unadjusted prevalence of asthma (8.86% vs. 13.54%, p = 0.04) and wheeze (15.7% vs. 23.26%, p = 0.003), but not bronchitis (3.94% vs. 4.48%, p = 0.62), was lower among children residing in households that reported not using a gas stove for heat compared to households that used a gas stove for heat. In unadjusted models, asthma prevalence was also associated with gender, BMI, parental history of asthma or hay fever, household income < $20,000, and age group. The unadjusted prevalence of chronic bronchitis was associated with age, race-ethnicity, parental history of asthma or hay fever, indoor cigarette smoke, household income < $20,000, and census region. The unadjusted prevalence of wheeze was associated with age, parental history of asthma or hay fever, the presence of a pet with fur or a bird in the home, indoor cigarette smoke, race-ethnicity, household

Table 1 Mean percent prevalence with 95% confidence intervals of asthma, wheeze, and bronchitis among children aged 2–16 living in homes with gas stoves by different stove use habits[1]

	Ever diagnosed with asthma (N = 7,390)			Wheeze in past 12 months (N = 7,392)			Ever diagnosed with chronic bronchitis (N = 7,390)		
Variable	**No. cases**	**Prevalence (95% CI)**	***P-value*[2]**	**No. cases**	**Prevalence (95% CI)**	***P-value*[2]**	**No. cases**	**Prevalence (95% CI)**	***P-value*[2]**
Total cases	572	9.48 (8.87, 11.30)		1,422	16.58 (14.88, 18.28)		329	4.05 (3.08, 5.03)	
Vent used w/gas stove		*n = 7,378*			*n = 7,380*			*n = 7,378*	
Yes	260	8.07 (6.11, 10.59)	*0.11*	643	14.20 (11.79, 17.01)	*0.01*	134	3.17 (2.20, 4.53)	*0.02*
No	310	11.09 (8.42, 14.47)		776	19.30 (16.90, 21.95)		194	5.08 (3.85, 6.67)	
Gas stove used for heating		*n = 7,346*			*N = 7,348*			*n = 7,346*	
Yes	117	13.54 (9.46, 19.03)	*0.04*	278	23.26 (18.35, 29.03)	*0.003*	74	4.48 (2.73, 7.25)	*0.62*
No	447	8.86 (7.16, 10.92)		1,133	15.70 (14.05, 17.52)		251	3.94 (3.03, 5.09)	
Vent and Stove Use		*n = 7,334*			*n = 7,336*			*n = 7,334*	
Vent not used and stove used for cooking and heating	78	13.63 (8.59, 20.97)	*0.13*	197	25.07 (18.58, 32.91)	*0.003*	60	5.43 (3.51, 8.33)	*0.10*
Vent used and stove used for cooking and heating	39	13.40 (7.41, 23.03)		81	20.14 (13.84, 28.38)		14	2.82 (1.09, 7.08)	
Vent not used and stove only used for cooking	224	10.36 (7.48, 14.18)		*568*	18.13 (15.59, 20.99)		130	4.87 (3.52, 6.72)	
Vent used and stove only used for cooking	221	7.67 (5.63, 10.35)		*562*	13.76 (11.32, 16.63)		120	3.20 (2.19, 4.65)	

[1]Unweighted sample sizes and weighted proportions (prevalence).
[2]P-values obtained from χ2 test.

income < $20,000, and BMI. Parental education and urban versus rural residence were not associated with any health outcomes (data not shown).

Multivariate logistic regression models were used to evaluate the odds of chronic respiratory illnesses in children who lived in homes where gas stoves were ventilated and only used for cooking while adjusting for other confounders (Table 2: Model 1). After adjusting for confounders, children who lived in homes where parents reported that they used ventilation were less likely to be diagnosed with asthma (aOR = 0.64, 95% CI: 0.43, 0.97), diagnosed with chronic bronchitis (aOR = 0.60, 95% CI: 0.37, 0.95), or report wheeze (aOR = 0.60, 95% CI: 0.42, 0.86). When parental habits regarding using a gas stove for heating were included as an additional covariate (Table 3: Model 2), only wheeze (aOR = 0.62, 95% CI: 0.44-0.89) and chronic bronchitis (aOR = 0.61, 95% CI: 0.38-0.98) remained significantly associated with vented gas stoves after adjusting for other confounders (p = 0.01 and p = 0.04, respectively). In homes where parents reported using gas stoves only for cooking and not heating, children were significantly less likely to have a diagnosis of

Table 2 Adjusted Odds ratios and 95% confidence intervals for the association between respiratory illnesses in children aged 2–16 years who live in households that use gas stove with ventilation compared to households that use gas stoves without ventilation (Model 1)

	Ever diagnosed with asthma[a] (N = 5,745)		Wheeze in past 12 months[b] (N = 5,744)		Ever diagnosed with bronchitis[c] (N = 7,255)	
Ventilation of gas stove	**No. cases**	**OR (95% CI)**	**No. cases**	**OR (95% CI)**	**No. cases**	**OR (95% CI)**
No	*269*	1 Ref.	*561*	1 Ref.	*188*	1 Ref.
Yes	*224*	0.64 (0.43, 0.97)*	*458*	0.60 (0.42, 0.86)*	*128*	0.60 (0.37, 0.95)*

*P-value <0.05.
[a]Adjusted for age group, sex, parental history of asthma or hay fever, and furry or feathery pets in the house, household income < $20,000, and BMI percentiles for age.
[b]Adjusted for age group, parental history of asthma or hay fever, furry or feathery pets in the house, indoor tobacco smoke, race-ethnicity, household income < $20,000, and BMI percentile for age.
[c]Adjusted for age group, parental history of asthma or hay fever, indoor tobacco smoke, race-ethnicity, household income < $20,000, and census region.

Table 3 Adjusted Odds ratios and 95% confidence intervals for the association between respiratory illnesses in children aged 2–16 years and gas stove use habits (Model 2)

	Ever diagnosed with asthma[a] (N = 5,646)		Wheeze in past 12 months[b] (N = 5,647)		Ever diagnosed with bronchitis[c] (N = 7,114)	
	No. cases	OR (95% CI)	*No. cases*	OR (95% CI)	*No. cases*	OR (95% CI)
Gas stove used with ventilation						
No	*263*	1 Ref.	*555*	1 Ref.	*184*	1 Ref.
Yes	*224*	0.68 (0.45, 1.04)	*458*	0.62 (0.44, 0.89)*	*128*	0.61 (0.38, 0.98)*
Gas stove used for heating						
Yes	*382*	1 Ref.	*795*	1 Ref.	*239*	1 Ref.
No	*105*	0.56 (0.34, 0.94)*	*218*	0.57 (0.38, 0.85)*	*73*	1.12 (0.66, 1.92)

*P-value <0.05.
[a]Adjusted for gas stove used for heating, age group, sex, parental history of asthma or hay fever, and pets in the house, household income < $20,000, and BMI.
[b]Adjusted for gas stove used for heating, age group, parental history of asthma or hay fever, pets in the house, indoor tobacco smoke, race-ethnicity, household income < $20,000, and BMI.
[c]Adjusted for gas stove used for heating, age group, parental history of asthma or hay fever, indoor tobacco smoke, race-ethnicity, household income < $20,000, and census region.

asthma (aOR = 0.56, 95% CI: 0.34-0.94) and wheeze (aOR = 0.57, 95% CI: 0.38-0.85), compared to children in homes that used a gas stove for cooking and heating after adjusting for other confounders. The odds of chronic bronchitis, however, was not significantly different for households that used a gas stove only for cooking compared to households that used a gas stove for cooking and heating (aOR = 1.12, 95% CI: 0.66-1.92) after adjusting for other confounders.

Table 4 examined the potential for joint effects of ventilation practices and using the gas stove for heating on respiratory illness in children. Compared to children living in homes where parents reported not using ventilation and who also used the gas stove for heat, using ventilation lowered the odds of asthma in children by 14%; not using the stove for heat lowered the odds by 38%; and using ventilation and not using the stove for heat lowered the odds by 59%. Similar results were found for wheezing. However, no significant association was observed for the joint effect of ventilation and using the gas stove heat on the odds of chronic bronchitis.

The relationship between lung function and behavioral factors related to gas stoves are presented in Table 5. The FEV_1 measurements ranged between 468 mL to 5683 mL with a weighted mean and standard deviation of 2658 mL and 882 mL. The FVC measurements ranged between 864 to 6846 mL with a weighted mean and standard deviation of 3069 mL and 1036 mL. For the FEV_1/FVC ratio, we observed a range between 31.6% and 100% with a weighted mean and standard error of 86.9% and 0.2%. Among children aged 8–16 years who provided spirometry measurements, unadjusted mean FEV_1 and FVC were higher in children who lived in homes where parents used an exhaust vent compared to children who lived in homes where there was no exhaust vent or parents reported not using the exhaust vent when operating their gas stoves (Table 5). Table 6 compares the percent of predicted (or normalized) differences in spirometry measurements among children aged 8–16 years in households that operated gas stoves with ventilation compared to households that operated gas stoves without ventilation. In fully adjusted models, the overall percent-predicted FEV_1 ($p = 0.08$), FVC ($p = 0.20$) and FEV_1/FVC ($p = 0.11$) were modestly higher in children living in homes with vented gas stoves compared to homes without ventilation of gas stoves, although these did not reach statistical significance (Table 6). Although after stratifying by sex, we observed that the percent-

Table 4 Adjusted Odds ratios and 95% confidence intervals for respiratory illnesses in children aged 2–16 years and the joint association between ventilation (yes/no) and gas stove use habits (cooking only/cooking and heating)

	Asthma[a] (N = 5,646)		Wheeze[b] (N = 5,647)		Bronchitis[c] (N = 7,114)	
	No. cases	aOR (95% CI)	*No. cases*	aOR (95% CI)	*No. cases*	aOR (95% CI)
Vent not used and stove used for cooking & heating	*69*	1 Ref.	*156*	1 Ref.	*59*	1 Ref.
Vent used and stove used for cooking & heating	*36*	0.86 (0.34, 2.17)	*62*	0.62 (0.31, 1.20)	*14*	0.49 (0.21, 1.12)
Vent not used and stove used only for cooking	*194*	0.62 (0.32, 1.23)	*399*	0.57 (0.35, 0.92)*	*125*	1.05 (0.61, 1.81)
Vent used and stove used only for cooking	*188*	0.41 (0.23, 0.74)*	*396*	0.35 (0.21, 0.60)*	*114*	0.65 (0.36, 1.19)

*P-value <0.05.
[a]Adjusted for age group, sex, parental history of asthma or hay fever, household income < $20,000, pets in the house, and BMI.
[b]Adjusted for age group, parental history of asthma or hay fever, pets in the house, indoor tobacco smoke, race-ethnicity, household income < $20,000, and BMI.
[c]Adjusted for age group, parental history of asthma or hay fever, indoor tobacco smoke, race-ethnicity, household income < $20,000, and census region.

Table 5 Univariate association between behaviors related to gas stove use and spirometry measurements for FEV_1 (mL), FVC (mL) and FEV_1/FVC Ratio in children aged 8–16 years

	N	Mean FEV_1 (95% CI)	Mean FVC (95% CI)	FEV_1/FVC (95% CI)
All	*2,472*	2658 (2586, 2730)	3069 (2977, 3161)	86.9% (86.5, 87.3)
Vented Gas Stove				
Yes	*1,147*	2742 (2645, 2841)*	3147† (3027, 3267)	87.4% (86.8, 88.0)
No	*1,325*	2562 (2457, 2668)	2981 (2850, 3113)	86.4% (85.8, 87.1)
Gas Stove Used for Heating				
Yes	*441*	2569 (2385, 2755)	2963 (2751, 3175)	86.9% (85.9, 87.9)
No	*2,017*	2670 (2595, 2744)	3084 (2989, 3179)	86.9% (86.5, 87.3)

*p-value ≤0.05.
†0.05 < p-value ≤ 0.1.

predicted FEV_1 was almost 3% higher in girls (p = 0.02) that lived in homes where parents reported using ventilation compared to homes where ventilation was not used. There was no significant association between venting of gas stoves with FVC in girls (p = 0.13). The percent-predicted FEV_1/FVC ratio was 1.6% (95%CI: 0.16, 3.0, p-value = 0.03) higher among girls living in homes that reported vent usage compared to girls in homes that reported not using ventilation with gas stoves (Table 6). No associations between spirometry measurements and ventilation were observed in boys. In addition, no association between spirometry and heating with a gas stove were observed overall or in the sex-stratified analysis.

Discussion

The results show that among children who live in households with a gas stove kitchen appliance, the prevalence of respiratory illness was lowest in children when ventilation was used when operating the gas stove and when the gas stove was not used for heat. Our finding support previous analysis of NHANES III by Lanphear et al. [28], which found that using a gas stove for heating increased the likelihood of asthma in children. Our analysis suggests that ventilation is likely an effect modifier of this association. Furthermore, we observed better lung function in children living in households where ventilation was used when operating the gas stove than in households that did not have ventilation or where no ventilation was used. This association with lung function was only significant in girls and it is unclear whether this stems from a greater sensitivity to gas stove emissions or differential behaviors that would result in more frequent exposure to gas stoves. Children's lung function, however, was not associated with parental report of using the gas stove for heat.

While indoor air pollution measurements are not available in NHANESIII, there is considerable evidence that gas stoves emit pollutants that adversely impact respiratory health and lend biological plausibility to our findings. Gas cooking and heating are a major source of nitrogen dioxide in the indoor environment [34-36]. In animal models, dose-dependent effects of nitrogen dioxide include activation of nuclear factors (NF-kB) within airway epithelial cells, resulting in neutrophilic inflammation and increased release of inflammatory cytokines [47]. Other mechanistic studies have consistently described that nitrogen dioxide has adjuvant properties in the development of allergic asthma by promoting eosinophilia, and the production of antigen-specific IgE and IgG antibodies [48]. In epidemiological studies, short- and long-term exposure to nitrogen dioxide has been inversely associated with FEV1 in pediatric populations [49,50]. A recent prospective epidemiological study found a higher

Table 6 Differences in percent of predicted spirometry (observed/predicted*100%) indicators among children aged 8–16 years in households that operated gas stoves with ventilation compared to households that operated gas stoves without ventilation that is stratified by gender (females N = 1,192; males N = 1,186)

		FEV_1 (Crude)	FEV_1 (Adjusted)[a]	FVC (Crude)	FVC (Adjusted)[a]	FEV_1/FVC (Crude)	FEV_1/FVC (Adjusted)[a]
		Difference[b] (95% CI)	Difference[b] (95% CI)	Difference[b] (95% CI)	Difference[b] (95% CI)	Difference[b] (95% CI)	Difference[b] (95% CI)
	N	*2,378*	*2,335*	*2,3378*	*2,335*	*2,378*	*2,335*
All	*1113*	2.75 (0.29, 5.21)*	2.33 (−0.29, 4.95)	2.08 (−0.66, 4.82)	1.75 (−0.95, 4.44)	1.14 (−.03, 2.31)	0.97 (−0.24, 2.17)
Female	*570*	2.86 (0.71, 5.01)*	2.93 (0.57, 5.30)*	1.6 (−0.4, 3.6)	1.76 (−0.51, 4.02)	1.45 (0.05, 2.85)*	1.58 (0.16, 3.00)*
Male	*543*	2.62 (−1.36, 6.61)	1.74 (−1.74, 5.24)	2.24 (−2.47, 6.96)	1.59 (−2.14, 5.32)	0.87 (−0.56, 2.30)	0.43 (−0.94, 1.81)

[a]Adjusted for environmental tobacco smoke, using a gas stove for heating, furry or feathery pets in the home, asthma status and household income < $20,000.
[b]NHANESIII reference spirometry measurements derived from Hankinson et al. [45].
*P-value <0.05.

risk of asthma morbidity among asthmatic children exposed to nitrogen dioxide levels below the US EPA outdoor air standard [51]. Polycyclic aromatic hydrocarbons (PAHs), another pollutant emitted from gas stoves, is also known to augment the allergic response by enhancing the release of inflammatory mediators in the immune system [52,53]. Polycyclic aromatic hydrocarbons are commonly found in association with fine particulate matter ($PM_{2.5}$), which has been inversely associated with FEV_1 in preschool children [54]. A recent case–control study in children found strong associations between environmental exposure to PAHs and multiple asthma-related biomarkers including IgE and inflammatory cytokines [55].

Using an exhaust fan can improve indoor air quality and reduce pollutants generated from gas stoves [9-16,56-58]. Thus, it is plausible that children who live in households that use exhaust fans when operating their gas stoves have better lung function and lower odds of respiratory illnesses. The assessment of the presence or absence of an exhaust fan in homes with gas stoves may be an important environmental factor to consider when taking an exposure history. Physicians, nurses, or health educators could encourage parents to use exhaust fans when operating gas stoves as an additional intervention for improving their children's respiratory health. Further, physicians, nurses and health educators could discourage the use of a gas stove as a household heating source.

It is important to note that this study has several limitations. While the study is generalizable to all U.S. non institutionalized children ages 2–16 years of age, it is cross-sectional and so we cannot comment on the temporal relationship between households with gas stoves, parental use of ventilation, and respiratory illnesses. NHANES III does not measure indoor air pollution levels which also limits our ability to quantitatively evaluate the relationship between gas stove emissions, ventilation practices, and respiratory outcomes. This analysis did not control for ambient air pollution concentrations because this data is not collected in NHANES and while it is possible to link NHANES data to ambient air pollution this would require access to restricted data that was outside the scope of this study. Nor did this survey collect information on the specific type of ventilation system or its effectiveness. Collecting information on the types of ventilation and its effectiveness by quantitatively measuring indoor air pollution in a nationally representative survey, like NHANES, would be very useful for future studies examining the relationship between gas stoves and respiratory health. Additionally, both the exposures and the outcomes in this study relied upon parental recall which may be a source of bias. It is therefore possible that respondents under-reported smoking behaviors which could explain why indoor smoke exposure was not a risk factor for asthma even though exposure to environmental smoke exposure was a risk factor for bronchitis in this sample. However, the consistency of our results between parental-reported respiratory illnesses in children and quantitative lung function measurements provide additional confidence in the association between ventilation practices and children's respiratory health. There were also missing observations, particularly for BMI because fewer people consent to the physiological measurement portion of the survey. However, when we analyze the data without BMI using the larger sample size, the statistical significance of the observed associations did not change in any meaningful way for asthma or wheeze (data not shown). Missing data could lead to selection bias but the consistency in the results (with or without BMI) makes this seem unlikely. Finally, the survey only queried respondents about ventilation if they indicated that they had a gas stove making it impossible to evaluate the effect of ventilation on respiratory outcomes in homes that electric stoves. Moreover, we opted to categorize ventilation usage using an extreme dichotomy (no exhaust fan or never use exhaust fan versus rarely, sometimes and always using exhaust fan) rather than four gradations of ventilation use (never, rarely, sometimes and always) because the division between rarely and sometimes is somewhat ambiguous and only 15 people with asthma and 17 people with bronchitis reported "rarely" using their exhaust fan.

Conclusion

This study observed that using a ventilating exhaust fan when operating a gas stove for cooking or heating was associated with a lower prevalence of asthma and other chronic respiratory symptoms in U.S. children after adjusting for other risk factors. Ensuring that ventilation is installed near gas stoves and that it is used when operating gas stoves is important, as is, only using gas stoves for cooking and not as an auxiliary heat source. The built environment and how people interact with their built environment, such as gas stoves, can change over time and it is important that national surveys continue to ask questions about gas stoves, ventilation, and behaviors related to their use in surveys that also collect information about children's respiratory health. Additionally, while the type of stoves and heating used in households are often considered by health care providers who are evaluating indoor air quality risk factors in pediatric patients, additional questions relating to the presence of an exhaust fan may provide an opportunity for preventive intervention and improved outcomes.

Additional file

Additional file 1: Figure S1. Description of the population selection criteria used to restrict to children aged 2-16 years of age who live in homes with gas stoves and have complete data for the covariates included in the multivariate regression models.

Abbreviations

CI: Confidence interval; FEV_1: Forced expiratory volume in 1 second; FVC: Forced vital capacity; NHANES: National Health and Nutrition Examination Survey; NOx: Nitrogen oxides; OR: Odds ratio; P: p-value; PAH: Polycyclic aromatic hydrocarbons; Pct: Percentile; SES: Socioeconomic status.

Competing interest

The authors declare that they have no competing interests.

Authors' contributions

MLK: Coordinated data analysis and interpretation, drafted the manuscript, and approved the final manuscript as submitted. ESC: Conducted the data analysis, contributed to the drafting of the manuscript, and approved the final manuscript as submitted. ES: Supervised the data analysis, critically reviewed the manuscript, and approved the final manuscript as submitted. DS: Contributed to data interpretation, contributed to manuscript draft, and approved the final manuscript as submitted. JM: Contributed to the review and interpretation of the statistical results and approved the final manuscript as submitted. AKH: Conceptualized the study design, contributed to drafting of manuscript, and approved the final manuscript as submitted.

Acknowledgements

This work was supported by grants from the US National Institute of Environmental Health Sciences NIEHS Grant P42 ES016465 and P30 ES000210.

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Received: 24 April 2014 Accepted: 25 August 2014
Published: 2 September 2014

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doi:10.1186/1476-069X-13-71
Cite this article as: Kile *et al.*: A cross-sectional study of the association between ventilation of gas stoves and chronic respiratory illness in U.S. children enrolled in NHANESIII. *Environmental Health* 2014 **13**:71.

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Indoor Air. Author manuscript; available in PMC 2016 June 15.

Published in final edited form as:

Indoor Air. 2014 August ; 24(4): 416–424. doi:10.1111/ina.12085.

Home interventions are effective at decreasing indoor nitrogen dioxide concentrations

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Abstract

Nitrogen dioxide (NO_2), a by-product of combustion produced by indoor gas appliances such as cooking stoves, is associated with respiratory symptoms in those with obstructive airways disease. We conducted a three-armed randomized trial to evaluate the efficacy of interventions aimed at reducing indoor NO_2 concentrations in homes with unvented gas stoves: (i) replacement of existing gas stove with electric stove; (ii) installation of ventilation hood over existing gas stove; and (iii) placement of air purifiers with high-efficiency particulate air (HEPA) and carbon filters. Home inspection and NO_2 monitoring were conducted at 1 week pre-intervention and at 1 week and 3 months post-intervention. Stove replacement resulted in a 51% and 42% decrease in median NO_2 concentration at 3 months of follow-up in the kitchen and bedroom, respectively ($P = 0.01$, $P = 0.01$); air purifier placement resulted in an immediate decrease in median NO_2 concentration in the kitchen (27%, $P < 0.01$) and bedroom (22%, $P = 0.02$), but at 3 months, a significant reduction was seen only in the kitchen (20%, $P = 0.05$). NO_2 concentrations in the kitchen and bedroom did not significantly change following ventilation hood installation. Replacing unvented gas stoves with electric stoves or placement of air purifiers with HEPA and carbon filters can decrease indoor NO_2 concentrations in urban homes.

Keywords

Indoor air; Nitrogen dioxide; Housing intervention; Urban environment; Gas stove; Air purifier

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Introduction

Nitrogen dioxide (NO_2), a by-product of combustion, is produced by several sources unique to the indoor environment, including gas stoves and gas heaters. Current evidence suggests that exposure to higher indoor NO_2 concentrations leads to symptoms in children with asthma, including chest tightness, shortness of breath, wheeze, cough, nocturnal symptoms, and an increased number of asthma attacks (Belanger et al., 2006; Garrett et al., 1998; Hansel et al., 2008). In addition, we have recently reported that exposure to higher indoor NO_2 concentrations is associated with increased respiratory symptoms and risk of COPD exacerbations in former smokers with moderate to severe COPD (Hansel et al., 2013).

Consequently, interventions that are successful at reducing indoor NO_2 concentrations may be beneficial to improving respiratory health in patients with obstructive lung diseases. In fact, current guidelines suggest that patients with asthma ‘avoid exposure to gas stoves and appliances that are not vented to the outside (Evidence C)’ and that ‘efficient ventilation, non-polluting cooking stoves, use of flues, and similar interventions are feasible and should be recommended (Evidence B)’ to patients with COPD (Global Strategy for Diagnosis, Management, and Prevention of COPD, 2013; National Heart, Lung, and Blood Institute National Asthma Education and Prevention Program, 2007). Despite these recommendations, very little is known about what home interventions will reduce indoor NO_2 concentrations.

In Baltimore City, like many urban communities, unvented gas stoves are common, and the presence of a gas stove in the home is independently associated with higher indoor NO_2 concentrations (Hansel et al., 2008). We designed a randomized, three-armed intervention trial to assess whether home interventions targeting unvented gas stoves can decrease indoor NO_2 concentrations and whether such interventions are feasible given the characteristics of each approach (Table 1). Homes in Baltimore City with unvented gas stoves were assigned to receive one of the following three interventions: (i) replacement of existing gas stove with an electric stove; (ii) installation of ventilation hood over existing gas stove; and (iii) placement of portable air purifiers in the home. To our knowledge, there have been no randomized trials that examine the impact of interventions focusing on gas stoves on concentrations of indoor NO_2 in residential environments.

Methods

Homes were recruited between June 2009 and March 2011 in partnership with the Baltimore City Health Department’s Healthy Homes Inspections and Health (HHIH) Services Program, which aims to reduce home-based factors that are major sources of health hazards and chronic health issues. Contact information of interested individuals receiving services from HHIH was forwarded to Johns Hopkins study staff, and individuals were contacted via telephone to determine whether their home was appropriate for randomization to assess the impact of home interventions on indoor NO_2 concentration. Preliminary eligibility was based on the following inclusion criteria: (i) the presence of unvented gas stove (combination cooktop and oven, fueled by gas, which is not ventilated with either a vented range hood or an overhead kitchen exhaust fan) and (ii) home occupant and home owner

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willing to provide informed consent. If eligible based on the telephone screening evaluation, homes were visited by a member of the study team for further evaluation and home assessment. In addition to the above criteria, homes were eligible if interventions were feasible based on home assessment, including sufficient electric service and structural design that did not prohibit interventions. Homes were ineligible if the home owner or home occupant planned to change residences within the study period or if there were foster children residing in the home. The study was reviewed and approved by the Johns Hopkins Medical Institutional Review Board. Written consent was obtained from the home owner.

Randomization

Randomization into one of the following three interventions was performed using block randomization by season. In our previous studies in Baltimore City, the NO_2 concentration was 16 ppb higher in homes with a gas stove compared with those without (Hansel et al., 2008). Using these data, sample size was calculated with an estimated 82% power to detect NO_2 changes in a similar magnitude pre- and post-intervention. Given the uncertainty of the ability of the air purifier to reduce NO_2 concentrations, and estimated only moderate compliance with air purifier use, a 1:1:2 (stove replacement: ventilation hood: air purifier) randomization scheme was employed to ensure a larger sample of homes receiving the air purifier.

- Stove replacement: Existing gas stoves were removed and replaced with stoves with electric resistance coils [including models from Roper™ (La Fayette, GA, USA), Maytag® (Benton Harbor, MI, USA), and Whirlpool® (Benton Harbor, MI, USA)] and convection and self-cleaning electric ovens. A general contractor was hired to install the stoves according to the manufacturer's guidelines.
- Ventilation hood: Range hoods [BROAN® (Hartford, WI, USA) Range Hood model numbers 433611, 403001, or 423001] with ventilation fans to the outdoors and secure seal to minimize energy loss were installed over existing gas stoves. The manufacturer lists the flow rates for the models used as 160–220 cubic feet per minute. A general contractor was hired to install the ventilation hoods according to the manufacturer's guidelines.
- Air purifier placement: Two ENERGY STAR® efficient air purifiers containing HEPA and activated carbon filters (Austin HealthMate®, Austin Air: Buffalo, NY, USA), which can adsorb gases including NO_2 (Rubel et al., 1995), were placed in the home. Manufacturer-provided flow rates are 75, 200, and 400 cubic feet per minute on the low, medium, and high settings, respectively. Participants were encouraged to use the air purifiers on the high setting. The filter has a life expectancy of 5 years and was therefore not changed during the study period. One air purifier was placed in the kitchen and the other in the main bedroom.

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Household inspection

All participants that were determined to be eligible based on the initial home assessment visit had home inspections and air quality assessment at baseline (1 or 2-weeks pre-intervention) and at 1 week and 3 months post-intervention. At the baseline visit, trained study staff completed a comprehensive home inspection with a focus on heating and cooling mechanisms, dryer type, and type of stove. At each follow-up visit, a briefer home inspection was completed that documented use of heating and cooling systems, the presence of smoking during the visit, and if the home had been assigned to the air purifier intervention, whether or not the air purifier was in use during the visit.

Environmental monitoring

Indoor air monitoring by trained technicians was completed over 7 days at each monitoring period. Week-long integrated NO_2 samples were collected using a passive sampler (Ogawa badge) loaded with filters coated with triethanolamine (TEA) placed in the kitchen and main bedroom (Palmes et al., 1976). The median limit of detection (LOD) was 2.03 ppb. All analytical batches included 10% field and laboratory blanks and duplicates.

To evaluate the relationship between ambient and indoor NO_2 concentrations, weekly ambient NO_2 concentrations from the Baltimore City EPA monitoring station #24-510-0040 were collected. All homes were located within 6 miles of the monitoring site.

Statistical analysis

We compared continuous variables using Student's two-tailed *t*-test or the Kruskal–Wallis test, as appropriate. We determined differences for categorical variables by Pearson's chi-square or Fisher's exact test, as appropriate. Post-intervention NO_2 concentrations were compared with baseline concentrations using the Wilcoxon–Mann–Whitney test. Log-transformed ambient and corresponding indoor NO_2 concentrations were compared for each baseline, 1-week, and 3-month monitoring period using Pearson's correlation. Subsequently, to evaluate the impact of season on effectiveness of interventions at reducing indoor NO_2 concentrations, the change in NO_2 concentration following intervention (at 1 week and 3 months) in homes that had their baseline visit during the Baltimore heating season (November 1–March 1, Baltimore Gas and Electric) was compared with those in the non-heating season using the Wilcoxon–Mann–Whitney test. Similar comparisons were made in homes that had gas furnaces vs. those without, and in homes with gas dryers vs. those without. All analyses were performed with Stata-SE version 12.0 (StataCorp, College Station, TX, USA). A two-tailed *P*-value < 0.05 was used to detect statistically significant differences.

Results

Two hundred and eighty-one home occupants expressed interest in the study, 39 of which failed the telephone screening [no longer interested ($n = 21$), did not want electric stove ($n = 15$), lived in apartment without landlord consent ($n = 2$), and already had electric stove ($n = 1$)]. Of the remaining 242 homes, 47 did not have a home assessment due to scheduling difficulties. One hundred and ninety-five homes underwent home assessments to determine

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eligibility. Fifty-seven of these homes did not meet eligibility because the stove was located too far from the exterior wall, and placing a ventilation hood to the outdoors was not feasible given the budget and capability of the general contractor. Thirty additional homes did not meet eligibility due to reasons including electrical limitations ($n = 7$), landlord objection ($n = 4$), lack of space for ventilation hood ($n = 4$), and an additional eight homes lost interest in the study prior to randomization. One hundred homes were randomized, of which 78 homes received an intervention, with 17 homes receiving an electric stove, 15 homes receiving ventilation hood, and 46 homes receiving air purifiers. Twenty-two homes did not receive intervention, mainly due to difficulty contacting the home owner to arrange for intervention or home owner dissatisfaction with randomization results (Figure 1). These homes did not have the baseline visit and thus did not undergo the home inspection.

Of the 78 homes receiving intervention, the majority of participants owned their home (89%), were African American (91%), and had a greater than high school education (56%). Less than half of home owners were employed, and home owners randomized to receive a ventilation hood were less likely to be employed (Table 2). The majority of homes had other gas appliances, including 91% with natural gas burning furnaces and 39% with gas-fueled clothes dryers. One quarter (25%) of homes had continuous pilot lights in their gas stoves. Approximately 30% of homes had any smoking in the home, and when present, overall smoking was low with the mean number of cigarettes smoked indoors per day of 2.9 ± 6.8 cigarettes. The median baseline NO_2 concentration was 17.9 ppb (range 3.2, 71.4), and 13.1 ppb (range 3.4, 41.8) in the kitchen and bedroom, respectively (difference between the kitchen and bedroom P-value < 0.01). Although homes receiving a ventilation hood tended to have lower baseline kitchen NO_2 concentrations, there was no statistical difference in baseline NO_2 concentrations between groups (Table 2).

At 1 week following the intervention, replacement of a gas stove with an electric stove resulted in a 44% decrease in the median kitchen NO_2 concentration, and 69% percent of homes receiving this intervention had a decrease in kitchen NO_2 concentrations. At 3 months post-intervention, replacement of a gas stove with an electric stove resulted in a 51% decrease in the median kitchen NO_2 concentration (Figure 2), and 88% percent of homes had a decrease in NO_2 concentrations (Table S1). In the bedroom, replacement of a gas stove with an electric stove resulted in a 31% decrease in median NO_2 at 1 week and a 42% decrease in median NO_2 concentration at 3 months (Figure 3). Three-quarters (75%) of homes had a decrease in NO_2 concentration at 3 months (Table S1).

Placement of air purifiers with HEPA and carbon filters resulted in a 27% decrease in median kitchen NO_2 concentration at 1 week, and 76% of homes receiving the air purifiers had a decrease in NO_2 concentration. At 3 months post-intervention, placement of air purifiers resulted in a 19% decrease in kitchen median NO_2 concentration (Figure 2) and two-thirds (66%) of homes had a decrease in kitchen NO_2 concentration (Table S1). In the bedroom, placement of air purifiers resulted in a 23% decrease in median NO_2 at 1 week, but NO_2 concentrations were not significantly different from baseline at 3 months of follow-up (Figure 3). 61% and 54% of homes had a decrease in NO_2 concentrations in the bedroom at 1 week and 3 months of follow-up, respectively (Table S1). The majority (85%) of homes

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in the air purifier intervention arm had the kitchen air purifier turned on during home inspection at the 3-month follow-up visit.

NO_2 concentrations in the kitchen and bedroom did not significantly change following ventilation hood installation ($n = 15$): (kitchen: median NO_2 at baseline = 12.2 ppb; median NO_2 at 1 week = 25.5 ppb, *P*-value compared with baseline = 0.14; median NO_2 at 3 months = 24.7 ppb, *P*-value compared with baseline = 0.11 and bedroom: median NO_2 at baseline = 13.1 ppb; median NO_2 at 1 week = 14.2 ppb, *P*-value compared with baseline = 0.68; median NO_2 at 3 months = 18.2 ppb, *P*-value compared with baseline = 0.18) (Table S2).

Kitchen NO_2 concentrations at 1 week were significantly different between the intervention arms (*P*-value = 0.04). In addition, there was a statistically significant difference in kitchen NO_2 concentrations between each intervention arm at 3 months of follow-up (*P*-value < 0.01). Bedroom NO_2 concentrations at 1 week were not significantly different between the intervention arms; there was a statistically significant difference in bedroom NO_2 concentrations between each intervention arm at 3 months of follow-up (*P*-value = 0.03; Table S2).

Median ambient NO_2 concentrations were 28.8, 29.8, and 28.9 ppb at baseline, 1 week, and 3 months, respectively. There was no statistically significant difference in ambient NO_2 concentrations across study visits for both the entire cohort and by study arm and no significant difference between study arms at each time period (Table S3). Furthermore, there was no statistically significant correlation between ambient NO_2 and indoor NO_2 concentrations at any visit across study arms (data not shown).

Because over 90% of our study homes had gas furnaces, it is difficult to determine whether the presence of a gas furnace modified the effect of our interventions. However, there was no statistically significant difference in the change in NO_2 concentrations (1-week baseline; 3-month baseline) between homes with natural gas heat and homes without, for each intervention group (all $P > 0.05$). Similarly, 38.5% of study homes had a gas dryer, and there was no statistically significant difference in the change in NO_2 concentrations between homes with a gas dryer and homes without, for each intervention group (all $P > 0.05$). While 13 homes in our study reported use of a space heater, all were electric and thus did not likely contribute to indoor NO_2 concentrations (data not shown).

Homes with stoves that had continuous pilot lights had higher baseline concentrations of NO_2 in both the kitchen and bedroom (kitchen: 27.1 vs. 14.8 ppb, $P < 0.01$; bedroom: 18.1 vs. 11.7 ppb, $P < 0.01$) compared with those with auto-ignite pilot lights. Subsequently, interventions, including stove replacement and placement of air purifiers, tended to be associated with a greater reduction in median NO_2 concentrations in homes with stoves with continuous pilot lights (Table S4).

Eighteen (23%) of homes had their baseline visit during the heating season of November 1–March 31. There were no statistically significant differences in the change in indoor NO_2 concentration at 1 week and 3 months of follow-up between homes with baseline visits in the heating vs. non-heating season (all $P > 0.05$).

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Discussion

To our knowledge, this is the first randomized intervention study focusing on gas stoves as the primary target of remediation of indoor NO_2 concentrations and shows that in-home interventions targeting gas stoves can reduce NO_2 concentrations in urban homes. Specifically, replacing unvented gas stoves with electric stoves reduced NO_2 concentrations by 51% and 42% in the kitchen and bedroom, respectively, indicating that stove replacement may impact NO_2 concentrations beyond the kitchen. Further, these reductions in NO_2 concentrations were observed despite the majority of homes having other gas-powered appliances such as gas furnaces and clothes dryers. In addition, placement of air purifiers with HEPA and carbon filters in the home results in a nearly 27% decrease in median kitchen NO_2 concentrations immediately (1 week after placement), and reductions are maintained at 3 months following intervention. These results show that simple home interventions may reduce indoor NO_2 concentrations and the results of this study can be used to guide future intervention studies assessing the health benefits of NO_2 exposure reduction.

We have previously shown that the presence of a gas stove was the largest contributor to indoor NO_2 concentrations in Baltimore homes, even in homes with a gas furnace (Hansel et al., 2008). This finding may be partly explained by Baltimore City building codes that specify ventilation requirements for furnaces, but do not require venting range hoods or other kitchen ventilation for gas cooking appliances. Furthermore, a recent study utilizing a simulation model suggests that 60% of homes using gas stoves without adequate ventilation will have NO_2 concentrations that exceed national health-based standards (Logue et al., 2013). Accordingly, replacing gas stoves with electric stoves was associated with the largest drop in indoor NO_2 concentrations. Furthermore, NO_2 concentrations were also decreased in the bedroom, indicating that replacing the predominant source of NO_2 may have a benefit throughout the home, not only the kitchen. The placement of an electric stove was associated with an initial $300–500 cost of the stove, plus the expense of installation. Although the increased cost of electricity may be an issue for lower income households, there are minimal potential additional costs once the stove is installed. Further, the efficacy of this intervention is not dependent on behavior or adherence (e.g., turning on the ventilation hood or air purifier).

We also found a significant decrease in NO_2 concentrations with the use of air purifiers with HEPA and carbon filters. Activated carbon filters in home air purification devices can adsorb NO_2 (Rubel et al., 1995). Our results support our previous post hoc analysis of a home intervention study showing decreased indoor NO_2 concentrations at 6 months of follow-up in homes outfitted with an air purifier with HEPA and carbon filter (Rusher et al., 2008). However, in the current study, sustained reduction in NO_2 concentrations was only observed in the kitchen; bedroom NO_2 concentrations at 3 months were no longer statistically different from baseline. As inspector-documented compliance was assessed only in the kitchen and not in the bedroom, we do not know whether or not the lack of improvement in bedroom NO_2 was due to lack of use of the air purifier in that location. Documented adherence to air purifier use was relatively high in this study (85% of kitchen air purifiers being turned on when home inspection occurred at 3 months), and prior research by our

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group has shown that even modest adherence (59%) to air purifier use can result in a decrease in indoor particulate matter (PM) concentrations and improved respiratory health in children with asthma (Butz et al., 2011). Given the previous studies showing the efficacy of air purifiers in reducing PM, air purifiers may be an attractive option for decreasing concentrations of multiple pollutants within the home, if PM reduction is also a goal. Furthermore, air purifiers may also target other potential sources of NO_2 in the home, not just stoves, and may be considered if additional sources of NO_2 are thought to be a major contributor to indoor NO_2 concentrations. Costs of air purifiers can be high, with additional ongoing costs required for replacement of filters and the energy cost of running the air purifiers.

Ventilation hood installation did not significantly reduce indoor NO_2 concentrations in our study, and there was a trend toward higher NO_2 concentrations in follow-up visits, although not statistically significant. The reason for the lack of efficacy of ventilation hoods is uncertain. Home inspection visits did not necessarily occur at times when stoves were in use to allow for inspector-documented adherence, and we did not ask participants to track ventilation hood use; thus, it is unclear if the lack of efficacy is due primarily to lack of use of the hoods. There may also have been changes in cooking behaviors that were unaccounted for. In addition, the overall function and ability of the ventilation hood to clear NO_2 remains largely unknown. Research by Singer et al. suggests that ventilation hoods have measured maximum airflows that are approximately 70% of reported manufacturer values (Singer et al., 2012). In addition, in studies of carbon dioxide, the capture efficiency (fraction of generated pollutants that are captured by range hood) varies highly among ventilation hood models and depends on location of burner use (front vs. back burners); models with high capture efficiency are often prohibitively loud for use in a residential environment (Delp and Singer, 2012). These studies, some of which are conducted in a controlled laboratory environment, highlight the potential variability in effectiveness of ventilation hoods, which would only be exacerbated when used in a real world, residential environment. It is also important to note that broad implementation of this intervention would be difficult in Baltimore homes as housing structure and kitchen design often made installation of ventilation hoods complex and costly, limiting the number of homes available for the intervention in our study.

Previously, only a few studies have examined the impact of modifying the indoor environment to decrease indoor concentrations of NO_2. In their non-randomized study of three apartment buildings in California, Noris et al. reported a decrease in indoor NO_2 in apartments receiving a variety of retrofits aimed at improving overall indoor air quality (Noris et al., 2013). The remainder of studies have focused primarily on the replacement of unvented gas heaters, two of which were conducted in schools. A randomized, double-blinded crossover study replacing unflued gas heaters with vented heaters in classrooms in Australia showed that classrooms with unflued gas heaters had concentrations of NO_2 that were nearly double those in intervention classrooms (31.6 ppb vs. 17.5 ppb). The higher concentration of NO_2 in non-intervention classrooms was associated with increased report of cough and wheeze among students (Marks et al., 2010). Similarly, Pilotto et al. replaced unflued gas heaters in eighteen public schools in Australia with flued gas heaters or electric heaters. Mean NO_2 concentrations post-intervention were 15.5 ppb in the classrooms

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receiving new heaters compared with 47 ppb in control classrooms. Frequency of asthma symptoms was lower in children with asthma in class-rooms receiving the intervention (Pilotto et al., 2004). A home intervention study in New Zealand showed that homes receiving more efficient heating devices (heat pumps, wood pellet burner, or high capacity flued gas heater) in place of unflued gas heaters had lower NO_2 concentrations than control homes. This decrease was associated with a reduction in asthma symptoms and healthcare utilization in children with asthma living in intervention homes. Symptom improvement occurred even though NO_2 concentrations were moderate low (4.5 ppb in intervention homes, 8.4 ppb in control homes) (Howden-Chapman et al., 2008).

Our baseline NO_2 concentrations were on average slightly higher than that reported in the homes in Howden-Chapman et al's. study, but lower than in our previous Baltimore City studies (30 ppb) (Hansel et al., 2008). Furthermore, our reduction in NO_2 concentrations achieved with replacement of a gas stove for electric stove, or placement of air purifiers with carbon filters, although modest, was similar to the degree of NO_2 reduction seen by gas heater interventions in the previous studies. Although it is possible that the observed percentage of homes that had a decrease in NO_2 could be attributable to natural temporal variability in NO_2 in a home without intervention, the statistically significant decrease in median NO_2 in the stove and air purifier intervention arms compared with the ventilation hood group suggests that these reductions were not due to chance alone. Importantly, reductions in NO_2 concentrations of a similar magnitude as those in this study have been linked with measureable health improvements in patients with asthma, suggesting that home interventions targeting gas stoves may result in reductions in NO_2 concentrations adequate to improve respiratory health in susceptible individuals.

Concentration of indoor NO_2 is impacted by many factors, including occupant behaviors, air exchange rates in the home, and ambient NO_2 concentrations (Schwab et al., 1994; Spengler et al., 1996). In our study homes, the correlation between ambient NO_2 and indoor NO_2 was not statistically significant, and thus, ambient NO_2 likely does not confound the relationship between the interventions and follow-up indoor NO_2 concentrations. Although the majority of homes in our sample were row houses and thus have similar construction characteristics, we did not measure home volumes or air exchange rates. Similarly, cooking frequency and duration was not measured, nor was use of the ventilation hood and bedroom air purifier. The lack of these measurements makes it difficult to account for the myriad of factors that impact NO_2 concentrations within a home. However, this study was designed to evaluate the overall efficacy of home interventions in real world, inner-city homes with typical appliance use. The changes in indoor NO_2 that were found in our study are reflective of how these interventions perform in homes without coaching or instruction to change daily activity patterns, and the magnitude of benefit of these interventions depends on each home's unique characteristics and occupant behavior patterns. Finally, our findings reflect the performance of these interventions in our study sample in Baltimore City and thus may not be generalizable to communities that differ from our study population.

In summary, we found that in homes with unvented gas stoves, replacing gas stoves with electric stoves or placing air purifiers with carbon filters reduces indoor NO_2 concentrations within 1 week and up to 3 months following intervention. Replacing the gas stove with an

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electric stove results in the greatest reduction in median NO_2 concentrations. Understanding the health benefit of reducing indoor NO_2 concentrations is an important next step in providing much needed information about the health effects of modifying the indoor environment. Such information is needed to continue to inform guideline development and provide tangible data to healthcare providers seeking to counsel patients with respiratory disease on exposures in their home environment.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

This study was made possible by funding from United States Department of Housing and Urban Development Grant #FR-5200-N-01A. We would like to thank Sarah Norman, Genevieve Birkby, and all of the staff of the Baltimore City Healthy Homes team. We are grateful to Austin Air® for the donation of the HealthMate® air purifiers used in the study. This work was supported by grants from the NIEHS (ES015781, ES015903, ES018176, R01ES022607) and the EPA (RD83451001).

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Practical Implications

Several combustion sources unique to the residential indoor environment, including gas stoves, produce nitrogen dioxide (NO_2), and higher NO_2 concentrations, are associated with worse respiratory morbidity in people with obstructive lung disease. A handful of studies have modified the indoor environment by replacing unvented gas heaters; this study, to our knowledge, is the first randomized study to target unvented gas stoves. The results of this study show that simple home interventions, including replacement of an unvented gas stove with an electric stove or placement of HEPA air purifiers with carbon filters, can significantly decrease indoor NO_2 concentrations.

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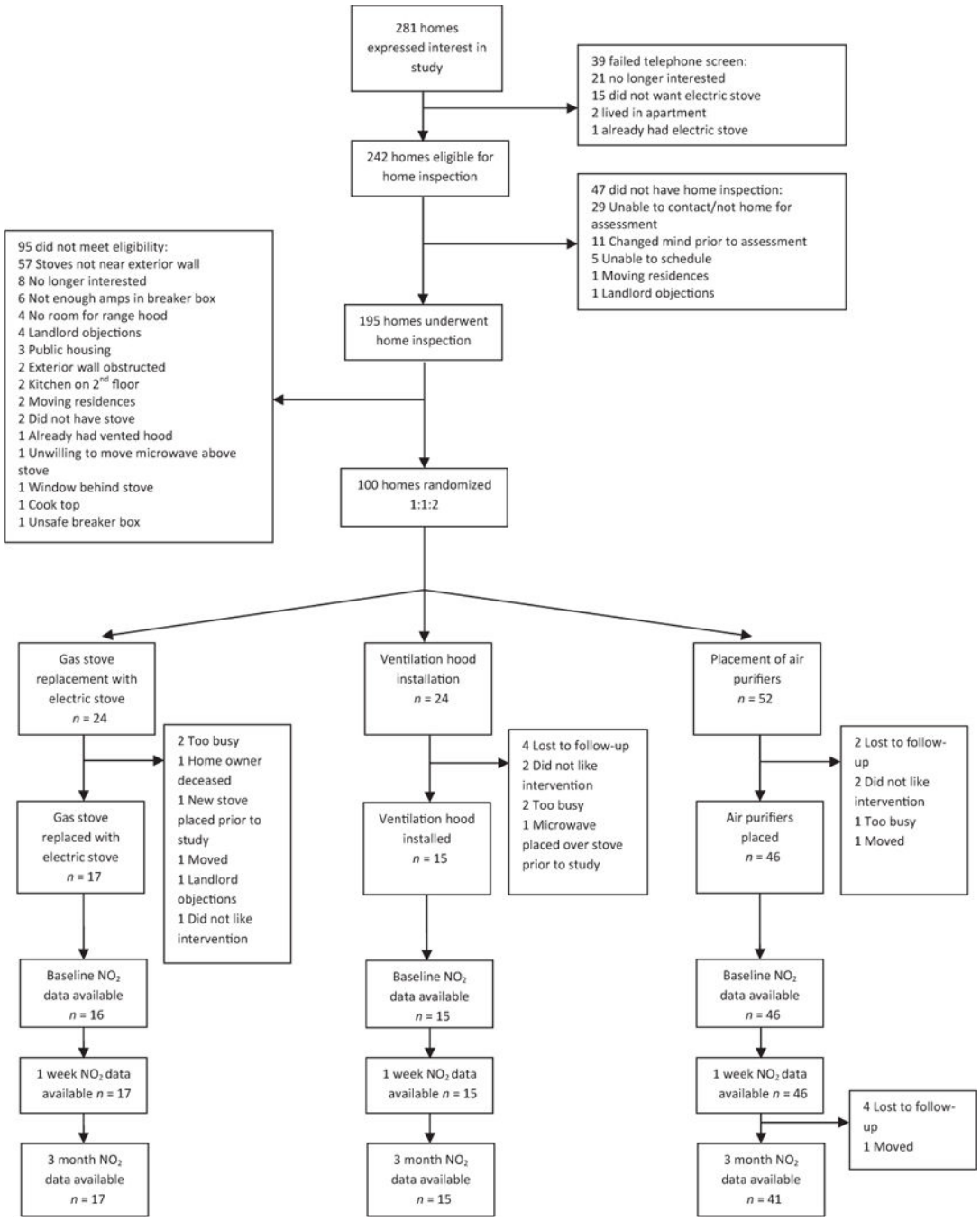

Fig. 1.

Flow diagram of study outlining home assessment, randomization into study branches, and follow-up of 3 months (NO_2 = nitrogen dioxide)

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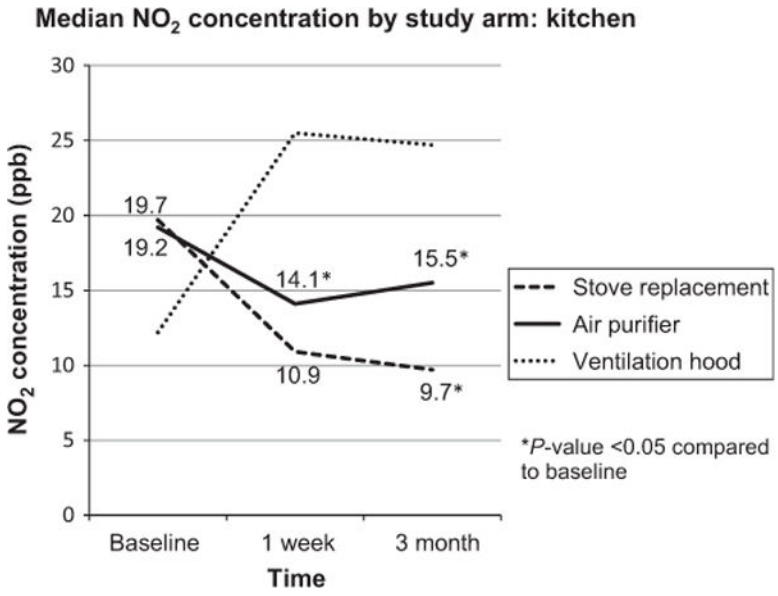

Fig. 2.

NO_2 concentrations by study arm: kitchen. Displays median kitchen NO_2 concentration for each study arm (stove replacement, air purifier, and ventilation hood) at baseline, 1-week, and 3-month follow-up. (NO_2 = nitrogen dioxide, ppb = parts per billion)

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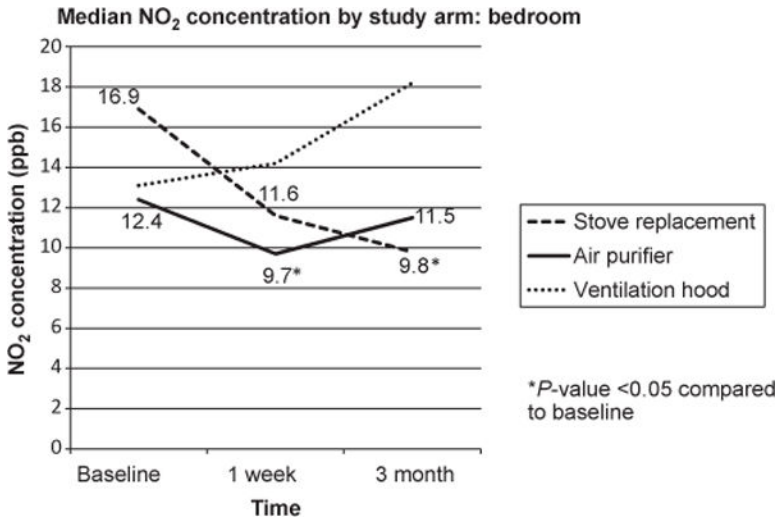

Fig. 3.

NO_2 concentrations by study arm: bedroom. Displays median bedroom NO_2 concentration for each study arm (stove replacement, air purifier, and ventilation hood) at baseline, 1-week, and 3-month follow-up. (NO_2 = nitrogen dioxide, ppb = parts per billion)

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Table 1

Characteristics of interventions. Qualitative comparison of each intervention arm (stove replacement, air purifier, and ventilation hood)

	Stove replacement	Air purifier	Ventilation hood
Equipment cost[a]	$390	$500	$65
Installation cost[a]	Professional installation required; $1875 (includes removal of old stove)	Easy to set up, no professional help needed	Professional installation required; $1,900
Operating cost[a]	Cost of electricity to operate stove	Cost of electricity to operate air purifier, cost of replacement air filters; $215	Cost of electricity to operate hood
Adherence	No additional steps needed to derive benefit	Must turn on to derive benefit	Must turn on to derive benefit
Maintenance	None required	Replacement of air filters according to manufacturer instructions	None required
Target of intervention	Addresses pollution derived from stove use	Addresses multiple potential sources of pollution	Addresses pollution derived from stove use

[a]The costs listed represent the average cost of the appliances used in this study but may vary depending on make/model purchased. Installation costs may vary depending on home infrastructure.

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Table 2

Home owner and housing characteristics. Descriptive data of participants and details of home and housing structure by total study population and by study arm (stove replacement, air purifier, and ventilation hood)

	All homes (*n* = 78)	Stove replacement (*n* = 17)	Air purifier (*n* = 46)	Ventilation hood (*n* = 15)
Home owner characteristics				
African American race, *n* (%)	71 (91.0)	16 (94.1)	42 (91.3)	13 (86.7)
Full- or part-time employment, *n* (%) *	29 (37.2)	7 (41.2)	19 (41.4)	3 (20.0)
>High school education, *n* (%)	44 (56.4)	8 (53.3)	28 (60.9)	8 (53.3)
Age, mean (SD)	53.5 (13.8)	52.0 (12.0)	51.5 (15.0)	59.0 (10.3)
Housing characteristics				
Reporting any smoking in home, n (%)	21 (27.3)	5 (29.4)	11 (24.4)	5 (33.3)
Owner occupied, n (%)	69 (88.5)	15 (88.2)	40 (87.0)	14 (93.3)
Row house, *n* (%)	67 (85.9)	13 (76.5)	41 (89.1)	13 (86.7)
Central air conditioning, *n* (%)	17 (21.8)	4 (23.5)	11 (23.9)	2 (13.3)
Natural gas furnace, *n* (%)	71 (91.0)	15 (88.2)	42 (91.3)	14 (93.3)
Gas dryer, *n* (%)	30 (38.5)	5 (29.4)	19 (41.3)	6 (40.0)
Continuous pilot light on stove, n (%)	19 (24.7)	5 (29.4)	11 (24.4)	3 (20.0)
[NO_2] in kitchen at baseline (ppb), median (range)	17.9 (3.2, 85.3)	19.7 (9.2, 70.2)	19.2 (6.8, 85.3)	12.2 (3.2, 53.3)
[NO_2] in bedroom at baseline (ppb), median (range)	13.1 (3.4, 41.8)	16.9 (6.9, 41.8)	12.4 (3.4, 35.1)	13.1 (5.3, 39.2)

NO_2, nitrogen dioxide; ppb, parts per billion.

* *P*-value < 0.05.

NIH Public Access
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Epidemiology. Author manuscript; available in PMC 2014 March 01.

Published in final edited form as:
Epidemiology. 2013 March ; 24(2): 320–330. doi:10.1097/EDE.0b013e318280e2ac.

Household levels of nitrogen dioxide and pediatric asthma severity

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Abstract

Background—Adverse respiratory effects in children with asthma are associated with exposures to nitrogen dioxide (NO_2). Levels indoors can be much higher than outdoors. Primary indoor sources of NO_2 are gas stoves, which are used for cooking by one-third of US households. We investigated effects of indoor NO_2 exposure on asthma severity among an ethnically and economically diverse sample of children, controlling for season and indoor allergen exposure.

Methods—Children aged 5–10 years with active asthma (n=1,342), were recruited through schools in urban and suburban Connecticut and Massachusetts (2006–2009) for a prospective, year-long study with seasonal measurements of NO_2 and asthma severity. Exposure to NO_2 was measured passively for four, month-long, periods with Palmes tubes. Asthma morbidity was concurrently measured by a severity score and frequency of wheeze, night symptoms and use of rescue medication. We used adjusted, hierarchical ordered logistic regression models to examine associations between household NO_2 exposure and health outcomes.

Results—Every 5 ppb increase in NO_2 exposure above a threshold of 6 ppb was associated with a dose-dependent increase in risk of higher asthma severity score (odds ratio= 1.37 [95%

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Conflicts of Interest: The authors have no conflicts of interest.

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confidence interval= 1.01 – 1.89]), wheeze (1.49 [1.09 – 2.03]), night symptoms (1.52 [1.16 – 2.00]) and rescue medication use (1.78 [1.33 – 2.38]).

Conclusions—Asthmatic children exposed to NO_2 indoors, at levels well below the US Environmental Protection Agency outdoor standard (53 ppb), are at risk for increased asthma morbidity. Risks are not confined to inner-city children, but occur at NO_2 concentrations common in urban and suburban homes.

Exposure to nitrogen dioxide (NO_2), a byproduct of combustion and a respiratory irritant,[1,2] can occur both indoors and outdoors. Gas appliances such as gas cooking stoves are primary sources indoors, where children spend large amounts of time. Gas stoves are used by approximately 39% of US households.[3] Indoor levels where NO_2 sources are present can be much higher than outdoors, where the primary source of NO_2 is traffic. Exposure to NO_2 continues to be a public health concern, especially with regard to the respiratory health of children with asthma.

A randomized controlled trial conducted in Australia has provided compelling evidence for an association between indoor NO_2 exposure and adverse respiratory outcomes among children with asthma.[4] The study, which involved replacing unflued gas heaters in selected schools with flued or electric heat, found improved average asthma morbidity over a 12-week period among students in the intervention schools. Two recent reviews of indoor environmental influences on asthma in children included NO_2 as an important potential trigger of asthma morbidity.[5,6] Both reviews summarized key studies dating back to the 1980's and concluded that there is limited but suggestive evidence of associations between indoor NO_2 exposure and asthma morbidity in children. Asthma morbidity measures used in studies of NO_2 exposure include number of symptom-days or nights (wheeze, persistent cough, shortness of breath, chest tightness), frequency of rescue medication use, peak expiratory flow (PEF), upper and lower respiratory tract symptoms, limited speech, and forced expiratory volume (FEV).[4,7–11] Many of these outcomes (especially symptoms and medication use) have limitations because they tend to be associated with access to healthcare and other socioeconomic factors. Confounding by these factors may account for some of the persistent inconsistency of asthma morbidity associations in the indoor NO_2-exposure literature.

We previously conducted a study of 728 asthmatic children and associations of symptoms with measured indoor NO_2,[7] and found increased risks of wheeze and chest tightness associated with increased levels of NO_2. Risks were confined, however, to children living in multifamily homes, a study characteristic associated with lower socioeconomic status, higher proportion of gas stove use and smaller proportion of asthma maintenance medication use. Analysis was based on a single NO_2 measurement per child and did not account for other important factors such as atopic status or indoor allergen exposure.

The current analysis characterizes the relationship between measured indoor NO_2 and concurrent asthma severity in a repeated measures analysis of a diverse population while considering some common mediating factors such as atopy, allergen exposure, seasonality, and socioeconomic status.

Methods

Participants

The Study of Traffic, Air quality and Respiratory health (STAR) was a prospective, one-year follow-up study of school-aged children with asthma. From 2006 through 2009, the study enrolled 1,401 children recruited through flyers distributed to schools in 23 cities and towns with gas lines in Connecticut and western Massachusetts. Volunteer families

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contacted the office and were screened (n = 2,175) via telephone. Eligible children (n = 1,642) were age 5–10 years, had a caregiver who spoke English and had active asthma defined as two or more of the following: physician diagnosis; asthma symptoms within the past 12 months (wheeze, persistent cough, chest tightness, shortness of breath); use of prescription asthma medication within the past 12 months (short-acting rescue medications and maintenance medications including inhaled steroids, systemic steroids, cromolyn, leukotriene inhibitors). The race/ethnicity distribution of children enrolled (i.e., those who completed a home interview and provided a blood sample) was similar to that of the towns where the children resided. Children (n = 1,342) who had complete information for health outcome measures and successful concurrent monitoring of indoor NO_2 were included in this analysis.

Data collection

At the time of enrollment, a research assistant visited the home, obtained consent, and interviewed the mother or primary caregiver (respondent) to obtain demographic data (age, sex, race/ethnicity, mother's education) and medical history of the child. The research assistant also observed and recorded housing type (single- or multi-family) and cooking appliance (gas or electric) of the enrollment residence. The mother was given a calendar to record daily symptoms and medication use.

At the end of each of the four, month-long monitoring periods, a research assistant phoned the respondent to obtain reports of daily symptoms and medication use and data on smoking in the home during the monitoring period. Sampling seasons were defined by winter and summer solstice and vernal and autumnal equinox. The midpoint of the observation period was used to assign the observation to a season.

At the end of one year, an exit interview was conducted via telephone. At this time a detailed address history was collected and the respondent provided housing characteristics such as housing type and type of cooking stove in each residence during the study. Housing type was later confirmed for all addresses with publicly available tax-assessor records.

Nitrogen dioxide (NO_2) measurement

At the enrollment visit, the research assistant placed passive monitors (Palmes tubes)[12] to measure NO_2 in rooms where the child spent the most time awake (dayroom) and asleep (bedroom). After one month, the respondent was contacted via telephone and instructed to cap the NO_2 monitors and return them in a pre-paid mailing envelope provided. Additional monitors were sent at three-month intervals for repeat sampling.

Palmes tubes were analyzed for NO_2 concentration.[12] Duplicate samples and field blanks were used for quality control. Regression analysis of duplicate samples (n=183) produced an adjusted $R^2 = 0.91$ with a slope = 0.96 and intercept = 0.84. Coefficients of variation for the dayroom, dayroom duplicates, bedroom, and bedroom duplicates were 95.3, 94.5, 120.4 and 116.8 respectively. Dayroom and bedroom concentrations of NO_2 were highly correlated (r = 0.89). In the present analysis, indoor NO_2 concentrations are defined as the average of the two indoor measurements per home for each monitoring period. Measurements matching monitoring periods with complete health data were used for analysis (n = 4,499). Quintile concentration boundaries (in ppb) were ≤ 4.02, > 4.02 – 6.02, 6.03 – 8.88, 8.89 – 14.32, > 14.32.

Environmental sampling and allergy testing

At the enrollment visit, the research assistant collected dust from the main living area for measurement of common allergens, using a protocol described previously.[7,13,14] Dust

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samples were assayed by enzyme-linked immunosorbent assay (ELISA) for detectable levels of dust mite allergens (*Der p* 1 ≥ 0.10 μg/g and *Der f* 1 ≥ 0.10 μg/g), cat allergen (*Fel d* 1 ≥ 0.12 μg/g), dog allergen (*Can f* 1 ≥ 0.12 μg/g) and cockroach allergen (*Bla g* 1 ≥ 0.60 U/g).

Using blood samples collected at the time of enrollment, serum for allergy testing was analyzed using the UniCAP system to determine total IgE and specific sensitivity to a panel of ten allergens. Atopy was defined as a sensitivity to any of the specific allergens, or as total IgE exceeding age-adjusted levels.[15] For each allergen (*Der p* 1, *Der f* 1, *Can f* 1, *Fel d* 1, *Bla g* 1) a binary variable was used that included allergen-specific sensitization and allergen-specific exposure[14]: for this analysis "1" indicated a specific sensitivity and detectable allergen in the home, "0" indicated no sensitization to the specific allergen or no detectable allergen in the home.

Asthma severity

An asthma severity score based on the Global Initiative for Asthma guidelines[16] was constructed for each observation period. The score was composed of two components: a symptom step and a medication step. We defined symptom steps as (0) no symptoms, (1) 1 – 3 symptom days and 0 –2 nights OR 0 days and any nights, (2) 4 – 19 symptom days OR 1 – 3 symptom days and 3 or more nights, (3) 20 or more symptom days OR 4 – 19 days and 5 or more nights, (4) more than 20 symptom days AND 10 or more nights. Medication steps were defined as (0) no asthma medication use, (1) rescue medication use only, (2) use of one controller medication (3) simultaneous use of two controller medications, (4) simultaneous use of three or more controller medications.

Symptom and medication steps were combined to determine overall asthma severity for each child in each monitoring period. A composite severity score of 0 was possible only if no symptoms were experienced and no asthma medication was used (symptom and medication step combination of (0, 0)). A score of 1 ("mild transient") was assigned for symptom and medication step combinations of (1, 1), (0, 1) or (1, 0) respectively. A score of 2 ("mild persistent") was assigned for symptom and medication step combinations of (2, 0), (2, 1), (0, 2) or (1, 2) respectively. Symptom and medications step combinations of (3, 0), (3, 1), (2, 2), (0, 3), (1, 3), respectively, were assigned a score of 3 ("moderate persistent"). Finally, a score of 4 ("severe persistent") was assigned if either the symptom or medication step was a 4 OR with symptom and medication step combinations of (3, 2), (3, 3), (2, 3). (See Figure 1 in the paper by Gent et al., 2012[14])

Additional outcomes of interest included frequency of wheeze, night symptoms and use of rescue medication. For analysis, we classified these into categories corresponding to symptom steps for the severity score: "0," "1 – 3," "4 – 19," and "more than 19" days per month.

Statistical analysis

Descriptive statistics and unadjusted associations between health outcomes, quintiles of NO_2 exposure, and covariates were computed with SAS version 9.2 (Cary, NC). We examined both unadjusted and adjusted associations with ordered logistic regression (proportional odds model). The proportional odds assumption for all outcomes was tested using NLMIXED in SAS in unadjusted models with quintiles of NO_2 exposure.

To allow for repeated measures of the health outcomes and exposure, we used a hierarchical ordered logistic model with a random term for subject. We assumed a normal distribution with unknown variance for subject effects. Associations between health outcomes and NO_2 exposures, both unadjusted and adjusted for covariates, were examined using a Bayesian

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approach with a Markov Chain Monte Carlo strategy implemented in OpenBUGS.[17] Bayesian estimates of model parameters were obtained by drawing samples from the posterior distribution using uninformative prior distributions (normal with mean zero and precision 1.0×10^{-6}) for model parameters in the linear predictor, flat priors with ordered ranges for the ordinal parameters, and a gamma prior (with shape = 0.001 and scale = 0.001) specified for precision for the random-subject effect. Estimates for final models were based on a sample of 10,000 iterations with thinning of 20 following burn-in of 20,000 iterations.

Initially, unadjusted models were constructed with exposure represented as quintiles of NO_2 concentration. We explored the shape of the exposure-response relationships between health outcomes and NO_2 using a natural spline function of the natural log (ln) of NO_2 [18] specifying 5 knots (at NO_2 concentrations representing the 10^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentiles of the distribution). Posterior means at exposure levels corresponding to the knots indicated that a threshold model would fit the data well and that the threshold was near the boundary of the second and third quintile of the NO_2 distribution. Thus, in adjusted models we combined the bottom two exposure quintiles. Linear trends above the threshold were examined in a fully adjusted model using ln NO_2 concentration as a continuous variable. Adjusted models for asthma severity score included age, sex, atopy, season of monitoring, race/ethnicity, mother's education, smoking in the home and all five variables for combined specific sensitization and exposure to indoor allergens (*Der p* 1*, Der f* 1*, Fel d* 1*, Can f* 1 *Bla g* 1). Models for wheeze, night symptoms and rescue medication included age, sex, atopy, season of monitoring, and all five variables for combined specific sensitization and exposure to indoor allergens (*Der p* 1*, Der f* 1*, Fel d* 1*, Can f* 1 *Bla g* 1), as well as maintenance medication use (which represents a critical aspect of disease severity not included in these outcome measures). Due to co-linearity with maintenance medication use, race/ethnicity, mother's education, and smoking in the home were excluded from models for wheeze, night symptoms and rescue medication.

Results

Each monitoring period was four weeks long, and all symptom and medication-use day counts were standardized to 28 days. The mean monitoring length was 33 (SD=7) days; median= 30 days; mode= 28 days. This analysis used NO_2 concentrations and health outcomes measured concurrently during 4,499 monitoring period observations contributed by 1,342 subjects. Of these, 870 (65%) subjects contributed complete asthma symptom, medication use and concurrently measured indoor NO_2 data for all monitoring periods; 202 (15%), 143 (11%), and 127 (9%) contributed data for 3, 2 or 1 monitoring periods, respectively. Out of 4,499 monitoring periods, 1,163 (26%) took place in summer, 1,092 (24%) in fall, 1,117 (25%) in winter, and 1,127 (25%) in spring.

Table 1 describes the enrollment characteristics of the study population. Just over half of children were age 5 – 7 years (52%) and male (59%). Two-thirds of the population were considered atopic (66%) and used maintenance medication at some point during the year of follow-up (66%). The population was 40% white, 19% African American, and 36% Hispanic. Only 16% of mothers had less than a high school education, while 29% were college graduates. At the time of enrollment, 10% of respondents reported having a smoker in their home. For four of the five allergens, less than one-third of the population was both sensitized and exposed (*Der p* 1 26%, *Der f* 1 29%, *Fel d* 1 29%, *Can f* 1 27%). Only 7% of children were both sensitized and exposed to cockroach (*Bla g* 1).

The mean daily indoor NO_2 level over all observations was 10.6 (SD=9.4) ppb, with interquartile range 4.5 – 12.5 ppb. Table 2 shows the distribution of all indoor NO_2 measurements (by quintile) over subject characteristics. White respondents were

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predominantly in the lower exposure quintiles, while African American and Hispanic families fell in the higher quintiles. Among women who did not complete high school, 7% are in the lowest exposure categories, while 37% are in the highest exposure categories. Among women who completed college, the distribution is reversed. Non-smokers were distributed fairly evenly across exposure quintiles while smokers were more often in the heavily exposed category. Indoor NO_2 measurements in the highest concentration quintile are most likely in the winter and least likely in the summer. For allergens *Der p* 1, *Der f* 1, *Can f* 1, and *Fel d* 1 17% of observations contributed by sensitized and exposed respondents fall into the highest NO_2 exposure categories compared with 34% of those contributed by respondents sensitized and exposed to *Bla g* 1.

Table 3 shows the distribution of asthma severity scores across subject characteristics. The most common level of symptoms was mild persistent (25%), and the least common was mild transient (10%). Atopic children were slightly less likely to be categorized as having no symptoms or medications during a monitoring period than non-atopic participants, but were no more likely to be categorized as severe. There were minor differences by ethnicity. Asthma severity scores were generally lower in the summer months and higher in the fall. Children who were both sensitized and exposed to *Der p* 1, *Der f* 1, *Fel d* 1, and *Can f* 1 were less likely to be in the severity score category 0 than non-sensitized or unexposed children.

Figure 1 displays the seasonal distributions of health outcomes. A comparison of Figure 1A with Figures 1B, 1C and 1D reveals a flat distribution of scores across asthma severity categories compared with the skewed distributions for categorized days of wheeze and night symptoms and somewhat less skewed distribution for rescue medication use. In general, summer is the season with lowest asthma severity (for all outcomes).

Figure 2 shows distributions of asthma severity score, wheeze and both rescue and maintenance medication use stratified by mother's education. The distributions for wheeze (Fig. 2A) and rescue medications (Fig. 2B) are similar: subjects whose mother did not complete high school were more likely to report wheeze (41%) and rescue medication use (54%) compared with children of mothers who completed high school (wheeze 35%, rescue medication use 46%) or college (wheeze 31%, rescue medication 45%). However, children of mothers who completed college were more likely (58%) to report use of maintenance medication compared with children of mothers who did not complete high school (46%) or college (47%) (Fig. 2C). Figure 2D shows that the asthma severity score, which incorporates both symptoms and medication use, is not associated with mother's education. Due to collinearity between maintenance medication and all socioeconomic variables, models for wheeze, night symptoms and rescue medication included maintenance medication use (an important indicator of disease status), but did not include race/ethnicity, mother's education, or smoking in the home.

The proportional odds assumption was satisfied for all outcomes in unadjusted models using quintiles of NO_2 exposure. Table 4 presents the results of Bayesian cumulative logistic regression models of associations between health outcomes and NO_2 exposure. In unadjusted models, compared with the lowest quintile of exposure (Table 4, unadjusted Model 1), the odds ratios for severity score imply a protective effect for exposure to NO_2 levels in the second two quintiles and an increased risk for exposure in the higher quintiles. A similar pattern is seen for night symptoms and rescue medication use and suggests a threshold for health effect. Unadjusted models using the combined lowest two quintiles as the reference group are shown in Table 4, unadjusted Model 2.

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Figure 3 illustrates, for fully adjusted models, the exposure-response relationships between NO_2 and health outcomes using a constrained, natural spline function of ln NO_2 and 95% confidence limits, as well as threshold functions for each outcome. In adjusted models of NO_2 exposure as quintiles (Table 4), levels greater than 14.3 ppb compared with the reference level (≤ 6 ppb, the threshold value) resulted in an increased risk of a one-level increase in asthma severity score (OR= 1.43 [95% CI= 1.08 – 1.88]). These same exposures were also associated with increased risks of wheeze (1.53 [1.16 – 2.02]), night symptoms (1.59 [1.24 – 2.01]) and rescue medication use (1.74 [1.34 – 2.26]). In the fully adjusted threshold models, every 5-ppb increase in NO_2 exposure above 6 ppb was associated with a dose-dependent increase in asthma severity score (1.37 [1.01 – 1.89]) as well as asthma morbidity measured by wheeze (1.49 [1.09 – 2.03]), night symptoms (1.52 [1.16 – 2.00]) and rescue medication use (1.78 [1.33 – 2.38]).

Discussion

In this study of school-aged children we observed an association of increasing NO_2 concentration in the home with asthma severity assessed by a 5-level score, as well as with asthma morbidity measured by days of wheeze, night symptoms and rescue medication use. Analyses were based on repeated measures of both NO_2 and asthma outcomes controlling for atopic status and common household allergen exposures.

These associations are consistent with findings in the literature suggesting an association between NO_2 exposure at both relatively low and high levels, and increased asthma severity and morbidity.[4,7,9–11,19] The mean indoor NO_2 level over all 4,499 observations was 10.6 (SD=9.4) ppb and was 15.6 (10.4) ppb among observations from homes with gas stoves. Figure 3D (rescue medication use) displays a histogram of NO_2 levels measured in all subjects' homes as well as in homes with gas stoves. In our previous study, the mean indoor NO_2 for all observations was 14.5 (SD=15.2) ppb and was 25.8 (SD=18.1) ppb in homes with gas stoves.

Figure 1 in that publication[7] describes the distribution of NO_2 with respect to both stove type and housing type. The lower NO_2 levels in our current study reflects the expanded use of high-efficiency gas appliances, which can reduce residential gas usage by up to 30 percent.[20] Differences among studies in NO_2 distributions also can be attributed to variations in recruitment strategies. We enrolled both urban and suburban children residing in homes with either electric or gas stoves, and found a wide distribution of household NO_2 exposures.

In our previous study of children with asthma,[7] indoor NO_2 was associated with respiratory symptoms but only among children in multifamily housing (an indicator of lower socioeconomic status). To compare the two studies, we explored associations between housing type and respiratory symptoms in the current study and found that children living in multifamily housing were 75% more likely to wheeze, 68% more likely to have night symptoms, and twice as likely to use rescue medication (data not shown). However, we did not find a differential effect of housing type on the asthma severity score.

An important confounder of the association of indoor NO_2 exposure with asthma morbidity is socioeconomic status. Higher NO_2 concentrations were found in homes of minority children and children whose mothers reported the fewest years of education (Table 2). These children also reported less use of maintenance medication (Fig. 2). Three of our four outcome measures (frequency of wheeze, night symptoms and rescue medication use) represent only part of a child's disease status. For example, a child reporting no wheeze who is not also taking controller medication will have less severe asthma than a child with no

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wheeze who is taking maintenance medication. In order to control for this aspect of disease severity (which is not included in the outcome measure), we included maintenance medication use as a covariate in models exploring associations between symptoms and NO_2 exposure. Because use of maintenance medication is also associated with socioeconomic status, we did not include additional socioeconomic-status variables in the adjusted models for these outcomes. When these additional variables are added, the odds ratios for the association with NO_2 exposure are attenuated and the confidence intervals widen (for wheeze, OR= 1.03 [95% CI= 0.75 – 1.42]; night symptoms 1.16 [0.87 – 1.54]; and rescue medication use 1.24 [0.91 – 1.68]).

A strength of our study is that one of our outcome measures, the asthma severity score, incorporates both symptom frequency and medication use. The asthma severity score is not associated with the socioeconomic status variables (Table 3) included as covariates in adjusted models.

In the Inner City Asthma Study[10] among non-atopic children, those with high NO_2 exposure were more likely to have more than four symptom days in a two-week period, and more likely to have peak flow values < 80% of predicted values. That study found no association between NO_2 exposure and symptoms or peak flow among atopic children. In our study, atopic children were no less likely to experience an increased risk of asthma morbidity associated with increased NO_2 than their non-atopic counterparts. This finding is in agreement with the Baltimore Indoor Environment Study of Asthma in Kids,[9] whichfound that atopy did not modify the association between NO_2 and asthma symptoms.

Strengths of the current study include large sample size, seasonal repeated measurements of NO_2 concurrent with measurements of asthma symptoms and medication use and an asthma severity score not associated with socioeconomic variables. Associations between NO_2 and asthma were consistent across all outcome measures. Allergy testing and household-allergen sampling at the time of enrollment permitted inclusion of additional important household asthma triggers.[14] In addition, the hierarchical analysis permitted estimates of associations between, rather than within, subjects, across homes with different levels of exposure.

The focus of our analysis was on the health effects of indoor exposure to NO_2 measured with passive monitors placed in a child's home where they spend the major portion of their time. One limitation of the passive monitoring method is that it results in an integrated average NO_2 concentration and does not allow for measurement of peak exposures. Sources of NO_2 were not part of the statistical model, and in homes without indoor sources (such as gas appliances), the only source of NO_2 would be outside the residence. The current study included passive monitors placed outside of the residence.[21] It remains for future analyses to model the complex relationship between outdoor and indoor levels of NO_2 and health effects. For example, when outdoor levels are added as a variable to the adjusted, threshold model for asthma severity score (bottom of Table 4), the odds ratio for indoor NO_2 exposure became 1.21 (0.88 – 1.67) and 1.31 (0.95 – 1.83) for outdoor NO_2 exposure. One could argue that indoor levels of NO_2 already account for a child's home exposure to outdoor NO_2 and adding NO_2 concentrations measured outside of a residence results in overcontrolling for indoor levels. An alternative model might be one that adds only "residual" amounts above what is measured indoors. In this alternative model, where only "extra" NO_2 not accounted for in the indoor measurement is added, the odds ratio for indoor NO_2 exposure on the asthma severity score is 1.52 (1.06 – 2.18), and the odds ratio for outdoor NO_2 exposures is 1.20 (0.98 – 1.46). The child's exposure away from home was not assessed either through personal monitoring or by taking measurements in other environments such as school. We would not expect children to be exposed to sources of NO_2 (e.g. gas stoves, unvented gas heaters) in schools or other non-residential environments in our study area.

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Other limitations include the lack of biological measures of asthma (e.g., peak flow or spirometric measures) and lack of control for viral respiratory illness (another known trigger of asthma exacerbations with possible potentiating effects on NO_2 exposure in asthmatic children[8]).

Our results contribute to a growing body of literature associating low levels of NO_2 exposure with adverse respiratory outcomes in asthmatic children. Further, the apparent threshold for these effects in asthmatic children (6 ppb indoors) was comparable to the 10th percentile of mean levels measured outdoors[22] – far below the US EPA 53 ppb standard – and with increasing risk of adverse respiratory morbidity above that level.

Acknowledgments

Source of Funding: This work was funded by the NIH National Institutes of Environmental Health Sciences grant ES05410 (Brian P. Leaderer, PI; brian.leaderer@yale.edu).

We gratefully acknowledge Rashele Yarborough and the staff of the Center for Perinatal, Pediatric and Environmental Epidemiology for their contributions to the collection and analysis of study data.

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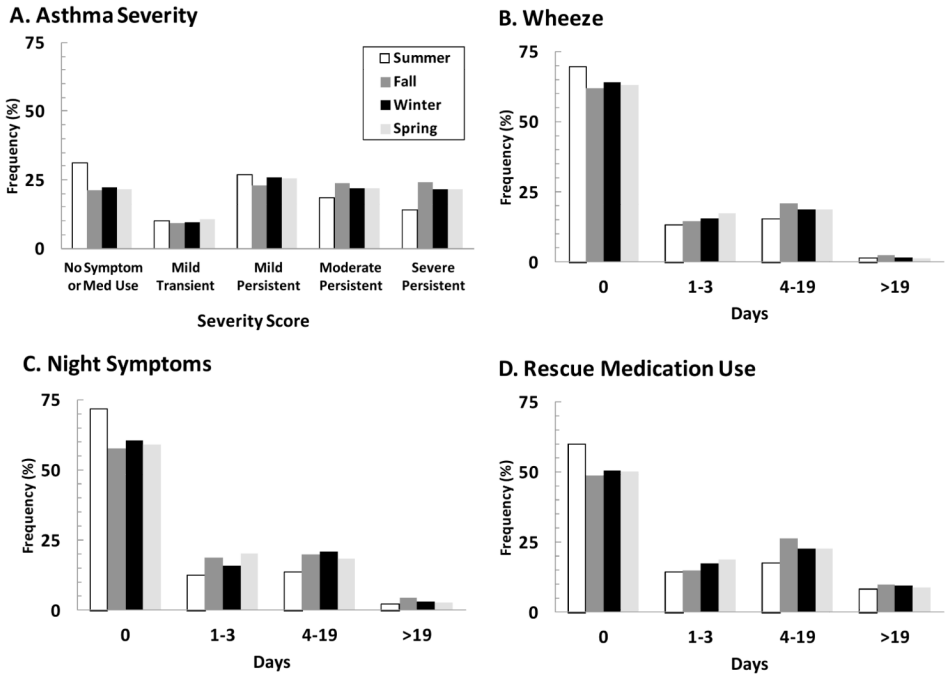

Figure 1.
Distribution of health outcomes: observations by season of monitoring for asthma severity score (A), days of wheeze (B), night symptoms (C) and rescue medication use (D).

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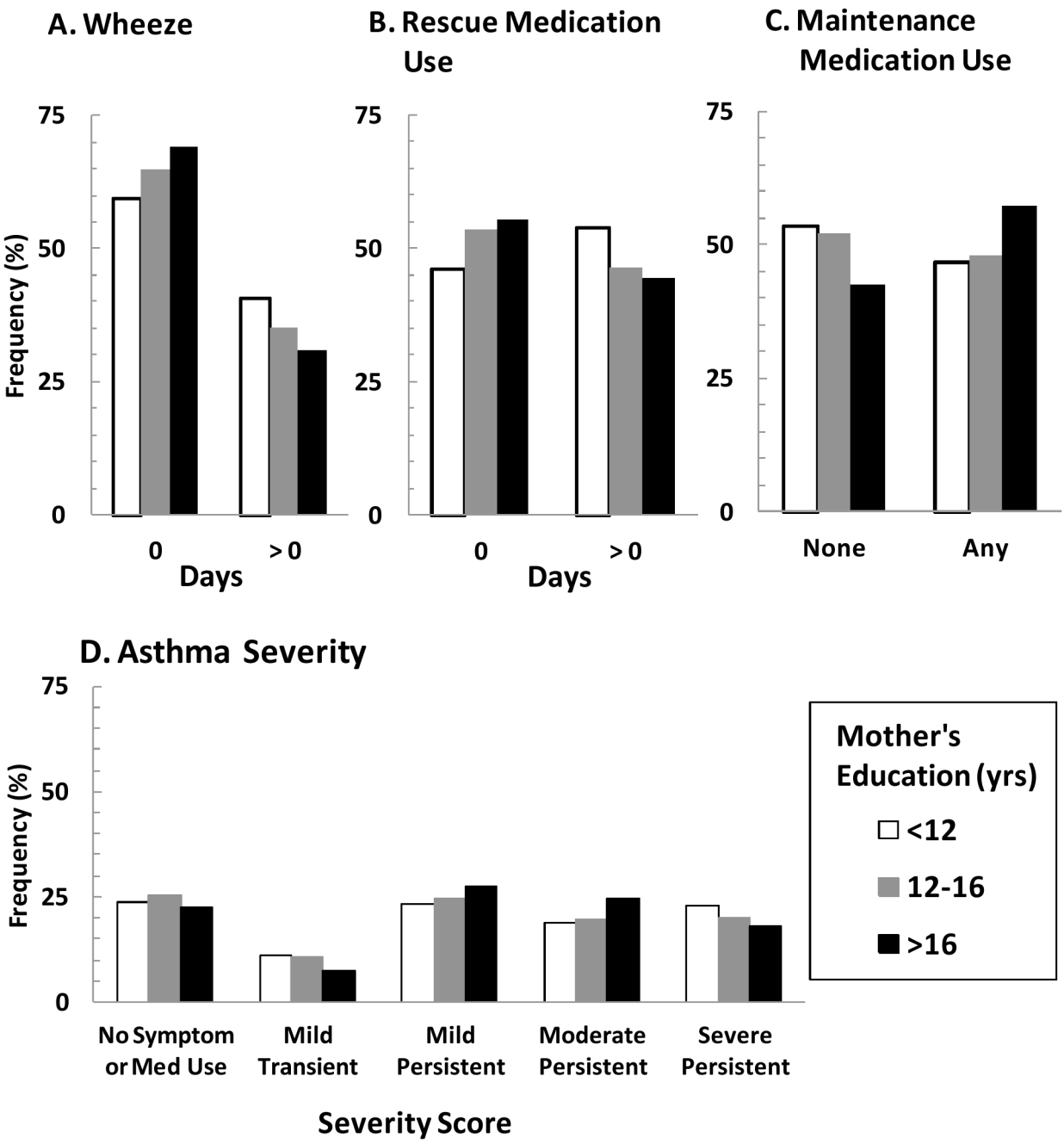

Figure 2.
Distribution of any wheeze (A), rescue medication use (B), maintenance medication use (C) and asthma severity score (D): observations for all monitoring periods by mother's education level.

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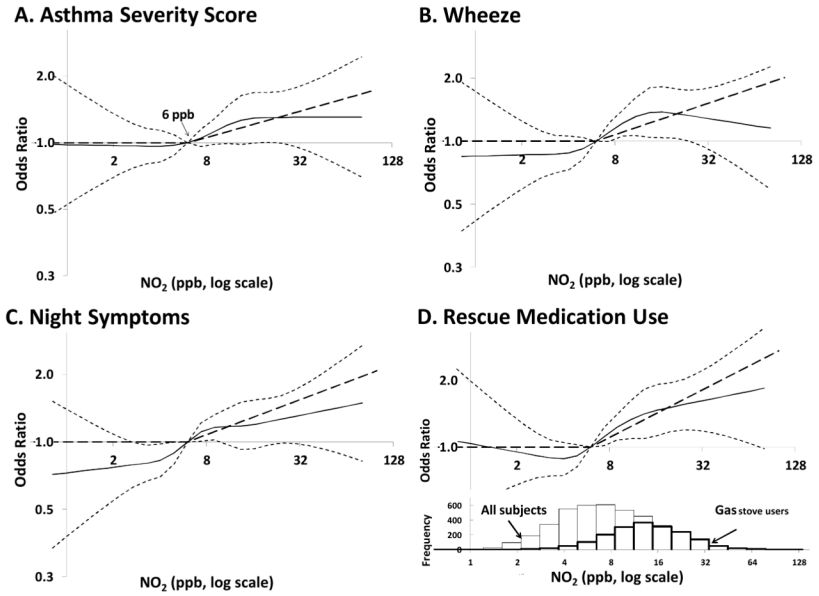

Figure 3.

Exposure-response relationships between health outcome and NO_2 (log concentration as a continuous variable) illustrated with constrained, natural spline functions (solid lines) with 95% confidence limits (small dashed lines) and threshold function (bold dashed line) from fully adjusted, hierarchical ordered logistic regression models for asthma severity score (A), wheeze (B), night symptoms (C), and rescue medication use (D). Also shown is a histogram of NO_2 levels measured in subjects' homes (panel D) for all observations (thin border) and observations taken in homes of gas stove users (bold border).

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Table 1

Characteristics of 1,342 asthmatic children enrolled from Connecticut and Massachusetts, 2006–2009.

Enrollment Characteristics	(n=1342) No. (%)
Age (yrs)	
5 – 7	703 (52)
8 – 10	639 (48)
Sex	
Boys	786 (59)
Girls	556 (41)
Atopic[a]	
No	451 (34)
Yes	886 (66)
Maintenance medication use[b]	
No	460 (34)
Yes	882 (66)
Race/Ethnicity	
White	538 (40)
African American	260 (19)
Hispanic	477 (36)
Mixed, Other	67 (5)
Mother's education (yrs)	
< 12	219 (16)
12 – 15	729 (55)
≥ 16	393 (29)
Smoking in the home	
No	1199 (90)
Yes	136 (10)
Allergens: Combined exposure sensitization status	
Dust mites	
***Der p 1* (μg/g)**	
< 0.10 or allergy absent	964 (74)
≥ 0.10 and allergy present	345 (26)
***Der f 1* (μg/g)**	
< 0.10 or allergy absent	919 (71)
≥ 0.10 and allergy present	380 (29)
Pets	
***Fel d 1* (μg/g)**	
< 0.12 or allergy absent	934 (71)
≥ 0.12 and allergy present	376 (29)
***Can f 1* (μg/g)**	
< 0.12 or allergy absent	952 (73)

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Enrollment Characteristics	(n=1342) No. (%)
≥ 0.12 and allergy present	360 (27)
Cockroach	
***Bla g 1* (U/g)**	
< 0.60 or allergy absent	1210 (93)
≥ 0.60 and allergy present	89 (7)

[a] General atopy defined as a positive response to any of the panel of allergens tested, or total IgE response above age-adjusted levels.

[b] Use of any maintenance medications during any of the four, month-long, monitoring periods during the year-long study.

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Table 2

Distribution of subject characteristics for quintiles of indoor nitrogen dioxide (NO_2).

		NO_2 Exposure Quintile (ppb)[a]				
		≤ 4.02 (n=899)	> 4.02 – 6.02 (n=900)	> 6.02 – 8.88 (n=900)	> 8.88–14.32 (n=900)	> 14.32 (n=900)
Characteristic	**Observations (n=4499) No.**	**%**	**%**	**%**	**%**	**%**
Age (yrs)						
5 – 7	2345	21	21	20	19	19
8 – 10	2154	18	19	21	21	21
Sex						
Boys	2665	20	21	20	20	19
Girls	1834	20	19	20	20	21
Atopic						
No	1490	20	19	18	20	23
Yes	2990	20	20	21	20	19
Race/Ethnicity						
White	1963	31	26	20	15	8
African American	817	10	15	20	23	32
Hispanic	1490	11	15	21	23	30
Mixed, Other	229	15	18	17	28	22
Mother's education (yrs)						
< 12	685	7	12	19	25	37
12 – 15	2363	16	18	21	22	23
≥ 16	1448	33	27	19	14	7
Smoking in the home						
No	4114	21	20	20	20	19
Yes	365	7	16	17	23	37
Season						
Summer	1163	18	21	24	23	14
Fall	1092	25	20	17	18	20
Winter	1117	20	18	19	19	24
Spring	1127	17	21	20	20	22

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Characteristic	Observations (n=4499) No.	NO_2 Exposure Quintile (ppb)[a] ≤ 4.02 (n=899) %	> 4.02 – 6.02 (n=900) %	> 6.02 – 8.88 (n=900) %	> 8.88–14.32 (n=900) %	> 14.32 (n=900) %
Allergens: Combined exposure sensitization status						
Dust mites						
***Der p 1* (μg/g)**						
< 0.10 or allergy absent	3206	20	19	20	20	21
≥ 0.10 and allergy present	1177	20	22	21	20	17
***Der f 1* (μg/g)**						
< 0.10 or allergy absent	3055	18	20	20	19	23
≥ 0.10 and allergy present	1291	23	20	21	21	15
Pets						
***Fel d 1* (μg/g)**						
< 0.12 or allergy absent	3084	18	20	20	20	22
≥ 0.12 and allergy present	1299	22	20	20	21	17
***Can f 1* (μg/g)**						
< 0.12 or allergy absent	3133	19	19	20	20	22
≥ 0.12 and allergy present	1256	22	22	21	19	16
Cockroach						
***Bla g 1* (U/g)**						
< 0.60 or allergy absent	4063	21	20	20	20	19
≥ 0.60 and allergy present	279	7	15	20	24	34

[a] Four, month-long integrated NO_2 samples were collected in each study subject's home, one sample per season.

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Table 3

Distribution of subject characteristics by asthma severity score.

		Asthma Severity Score[a]				
		None (n=1087)	Mild Transient (n=431)	Mild Persistent (n=1133)	Moderate Persistent (n=952)	Severe Persistent (n=896)
Characteristic	**Observations (n=4499) No.**	**%**	**%**	**%**	**%**	**%**
Age (yrs)						
5 – 7	2345	26	9	23	21	21
8 – 10	2154	22	11	28	21	18
Sex						
Boys	2665	25	9	24	22	20
Girls	1834	23	10	27	20	20
Atopic						
No	1490	28	9	24	19	20
Yes	2990	22	10	26	22	20
Race/Ethnicity						
White	1963	23	8	26	24	19
African American	817	25	13	25	19	18
Hispanic	1490	26	10	23	19	22
Mixed, Other	229	17	5	28	25	25
Mother's education (yrs)						
< 12	685	24	11	23	19	23
12 – 15	2363	25	10	25	20	20
≥ 16	1448	22	8	27	25	18
Smoking in the home						
No	4114	24	10	25	21	20
Yes	365	22	13	28	20	17
Season						
Summer	1163	31	10	27	18	14
Fall	1092	21	9	23	23	24
Winter	1117	22	9	26	22	21
Spring	1127	22	11	25	21	21

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Characteristic	Observations (n=4499) No.	Asthma Severity Score[a] None (n=1087) %	Mild Transient (n=431) %	Mild Persistent (n=1133) %	Moderate Persistent (n=952) %	Severe Persistent (n=896) %
Allergens: Combined exposure sensitization status						
Dust mites						
***Der p 1* (μg/g)**						
< 0.10 or allergy absent	3206	26	9	25	20	20
≥ 0.10 and allergy present	1177	20	10	25	25	20
***Der f 1* (μg/g)**						
< 0.10 or allergy absent	3055	26	9	24	21	20
≥ 0.10 and allergy present	1291	20	10	28	23	19
Pets						
***Fel d 1* (μg/g)**						
< 0.12 or allergy absent	3084	27	9	24	20	20
≥ 0.12 and allergy present	1299	19	10	27	24	20
***Can f 1* (μg/g)**						
< 0.12 or allergy absent	3133	26	9	25	20	20
≥ 0.12 and allergy present	1256	19	10	27	25	19
Cockroach						
***Bla g 1* (U/g)**						
< 0.60 or allergy absent	4063	25	9	25	21	20
≥ 0.60 and allergy present	279	24	13	26	15	22

[a]Health data (asthma severity score based on symptoms and medication use) were collected during four, month-long monitoring periods, one per season.

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Table 4

Results from ordered logistic regression models[a] of unadjusted and adjusted associations between exposure to indoor NO_2 (nitrogen dioxide) and risk of increased asthma severity (asthma severity score, wheeze, night symptoms and rescue medication use).

	Health outcomes[b]							
	Asthma Severity Score		Wheeze		Night Symptoms		Rescue Medication Use	
NO_2 exposure ppb[c]	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Unadjusted								
Model 1								
0 – ≤ 4.00[d]	1.00		1.00		1.00		1.00	
4.00 – ≤ 6.02	0.83	(0.67 – 1.03)	1.05	(0.81 – 1.36)	0.89	(0.71 – 1.12)	0.92	(0.73 – 1.16)
6.02 – ≤ 8.88	0.89	(0.70 – 1.12)	1.08	(0.81 – 1.43)	1.08	(0.84 – 1.37)	1.09	(0.85 – 1.40)
8.88 – ≤ 14.30	1.04	(0.81 – 1.34)	1.31	(0.98 – 1.75)	1.20	(0.94 – 1.54)	1.21	(0.94 – 1.59)
> 14.30	1.21	(0.92 – 1.59)	1.38	(1.02 – 1.87)	1.40	(1.09 – 1.81)	1.53	(1.16 – 2.02)
Model 2								
0 – ≤ 6.02[d]	1.00		1.00		1.00		1.00	
6.02 – ≤ 8.88	1.00	(0.82 – 1.21)	1.04	(0.83 – 1.31)	1.15	(0.94 – 1.41)	1.17	(0.93 – 1.42)
8.88 – ≤ 14.30	1.16	(0.94 – 1.44)	1.27	(1.00 – 1.63)	1.28	(1.03 – 1.59)	1.27	(1.02 – 1.61)
> 14.30	1.34	(1.06 – 1.71)	1.34	(1.03 – 1.73)	1.49	(1.18 – 1.87)	1.61	(1.25 – 2.06)
Adjusted[e]								
≤ 6.02 [d]	1.00		1.00		1.00		1.00	
6.02 – ≤ 8.88	1.15	(0.94 – 1.42)	1.15	(0.90 – 1.45)	1.36	(1.09 – 1.68)	1.29	(1.04 – 1.60)
8.88 – ≤ 14.30	1.31	(1.04 – 1.66)	1.44	(1.11 – 1.86)	1.41	(1.12 – 1.78)	1.43	(1.12 – 1.81)
> 14.30	1.43	(1.08 – 1.88)	1.53	(1.16 – 2.02)	1.59	(1.24 – 2.01)	1.74	(1.34 – 2.26)
Threshold model[f]	1.37	(1.01 – 1.89)	1.49	(1.09 – 2.03)	1.52	(1.16 – 2.00)	1.78	(1.33 – 2.38)

[a] To allow for repeated health outcome measures from each monitoring period, hierarchical mixed models with a random term for subject were used.

[b] Asthma severity score has 5 levels: 0 (no symptoms, no medication use), 1 (mild transient), 2 (mild persistent), 3 (moderate persistent), 4 (severe persistent). Health outcomes wheeze, night symptoms, and rescue medication use have 4 levels: 0 (no days of symptoms/medication use), 1 (1 – 3 days), 2 (4 – 19 days), 3 (> 19 days).

[c] Exposure to quintiles of NO_2 (ppb) were compared to the lowest quintile (for unadjusted Model 1) or threshold value (≤ 6.02 ppb, combined first and second quintiles, for unadjusted Model 2 and adjusted model). Separate models were run for each health outcome.

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[d] Reference category.

[e] Model for asthma severity score adjusted for: age, sex, general atopy, season, specific sensitization and exposure to five indoor allergens (*Der p 1*, *Der f 1*, *Fel d 1*, *Can f 1*, *Bla g 1*), race/ethnicity, mother's education, smoking in the home. Models for wheeze, night symptoms and rescue medication use were adjusted for: age, sex, general atopy, season, specific sensitization and exposure to five indoor allergens (*Der p 1*, *Der f 1*, *Fel d 1*, *Can f 1*, *Bla g 1*), maintenance medication use. Because of colinearity with maintenance medication use, socioeconomic status variables (race/ethnicity, mother's education, smoking in the home) were not included for these three outcomes.

[f] Linear trend of exposure-response relationship with the exposure as a continuous variable representing ln NO_2 values greater than the threshold (6.02 ppb). Odds ratios given as a 1.6 increase ln NO_2 concentration (5-fold increase in NO_2).

OR indicates odds ratio; CI, confidence interval.

Epidemiology. Author manuscript; available in PMC 2014 March 01.

Journal of the Air & Waste Management Association

ISSN: 1047-3289 (Print) (Online) Journal homepage: http://www.tandfonline.com/loi/uawm18

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To cite this article: Vic Hasselblad , David M. Eddy & Dennis J. Kotchmar (1992) Synthesis of Environmental Evidence: Nitrogen Dioxide Epidemiology Studies, Journal of the Air & Waste Management Association, 42:5, 662-671, DOI: 10.1080/10473289.1992.10467018

To link to this article: https://doi.org/10.1080/10473289.1992.10467018

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ISSN 1047-3289 *J. Air Waste Manage. Assoc.* **42:** 662–671

Synthesis of Environmental Evidence: Nitrogen Dioxide Epidemiology Studies

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The use of meta-analysis is becoming more common in the medical literature, but it is not common in the environmental literature. Although meta-analysis cannot combine a group of poorly executed, conflicting studies to get an unequivocal answer, there are certain situations where it can be helpful. The inability of studies to produce similar results may be a function of the power of the studies rather than a reflection of their quality. The literature on the effects of nitrogen dioxide on the odds of respiratory illness in children is such an example. Three quantitative methods for the synthesis of this evidence are presented. Although the methods produce slightly different results, the conclusion from all three methods is that the increase in the odds of respiratory illness in children exposed to a long-term increase of 30 μg/m³ (comparable to the increase resulting from exposure to a gas stove) is about 20 percent. This estimated increase is not sensitive to the method of analysis.

The U.S. Environmental Protection Agency (U.S. EPA) is directed by the Clean Air Act[1] to promulgate standards that protect the public health from air pollutants and are based on air quality criteria. Such criteria are to reflect the latest scientific information useful in indicating the kind and extent of all identifiable public health effects that may be expected from the presence of ambient air pollutants. Air Quality Criteria Documents (AQCDs) for these pollutants attempt to integrate and synthesize key information from several disciplines to provide a coherent framework from which interpretation and judgments can be made concerning the risk to human health. Reducing the uncertainties inherent in such information strengthens the conclusions that can be drawn.

Over the past decade, quantitative approaches have been developed to synthesize evidence from multiple studies. Making use of such approaches in evaluating and synthesizing epidemiologic evidence as part of AQCD preparation requires that the methods be able to handle the results of a variety of analyses, including multiple logistic regression analyses, and provide combined estimates of the probability of a given type of health effect occurring at a specified exposure level. This eliminated many meta-analysis methods often used with clinical trials, as well as the method of effect sizes. In preparing a revised AQCD for nitrogen oxides, three methods were found to be useful. These methods are described below, and comparisons are then made between the results of the three methods as applied to the evaluation and synthesis of epidemiologic evidence concerning the effects of nitrogen dioxide on respiratory disease symptoms in children.

The purpose of this paper is to: (1) demonstrate that there are situations where the synthesis of environmental evidence is feasible, (2) describe some of the models used for this synthesis, and (3) apply these models to a specific data set of interest.

Implications

The assessment methodology discussed, meta-analysis, provides an alternative approach for assessing environmental data bases. Meta-analysis has the potential to increase the ability to estimate a small but meaningful change in the risk of a health outcome measure by analyzing the total evidence from all studies simultaneously. The specific example of the relationship of lower respiratory illness and nitrogen dioxide (NO_2) exposure is a case in point. The evidence of the individual studies was inconclusive. When taken as a whole, the results of the meta-analysis suggest an increase of at least 20 percent in the odds of respiratory illness in children exposed to an increase of 30 μg/m³ NO_2. This analysis can be considered along with other evidence in assessing health effects of exposure to NO_2.

Quantitative Methods for Synthesizing Evidence

The three quantitative approaches employed in evaluating nitrogen dioxide (NO_2) health effects evidence are: (1) the variance-weighted method, (2) random-effects models as described by DerSimonian and Laird,[2] and (3) the Confidence Profile Method as described by Eddy[3] and Eddy et al.[4,5]

Variance-Weighted Method

One of the oldest methods for combining estimates of a parameter is the variance-weighted method, which is described by Hald.[6] Assume that there are n studies, each giving estimates, $\hat{\theta}_i$, of a parameter θ, where $i = 1,2,\ldots,n$. The method assumes that each study is independent of the other studies and that each study is estimating exactly the same parameter. We shall refer to this as the fixed-effects model. The minimum variance estimate for any estimate,

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which is a linear combination of the $\hat{\theta}_i$'s, is:

$$\hat{\theta} = \left[\sum_{i=1}^{n} w_i \times \hat{\theta}_i\right] \Big/ \left[\sum_{i=1}^{n} w_i\right] \quad (1)$$

where $w_i = 1/\text{variance}(\hat{\theta}_i)$. The statistic for testing the null hypothesis that all $\hat{\theta}_i$'s are estimating the same parameter is:

$$X^2 = \sum_{i=1}^{n} w_i(\hat{\theta}_i - \hat{\theta})^2 \quad (2)$$

which is approximately distributed as a chi-square distribution with $(n - 1)$ degrees of freedom.

Combining Random-Effects Models

Random-effects models have been used for many years, although they are sometimes called two-stage or hierarchical models. Random-effects models arise when the parameter or parameters of "mother nature" do not remain constant from study to study. Instead, they vary randomly and are in fact assumed to be random variables from some distribution. The problem then becomes to estimate (or derive a posterior distribution for) some function of these parameters.

One such random-effects model is the so-called "normal-normal" model. In this model we assume that each estimate, $\hat{\theta}_i$, of the parameter θ is sampled from a normal distribution with mean μ_i and variance σ_i^2. For now, we assume that σ_i^2 is known and that μ_i is a random value from another normal distribution with mean θ and variance τ^2. The likelihood for the estimates from n different studies is:

$$L \propto \exp\left[-\sum_{i=1}^{n} [(\hat{\theta}_i - \theta)^2/(\tau^2 + \sigma_i^2) + 1n(\tau^2 + \sigma_i^2)]/2\right] \quad (3)$$

The parameter θ can be estimated, or a posterior for θ and τ^2 can be calculated if prior distributions (priors) are specified for θ and τ^2. A flat prior $[p(\tau^2) \equiv 1]$ will work for τ^2, but the natural noninformative prior $1/\tau$, leads to problems. The integrals do not converge for τ^2 near zero, and the intergrals do not converge as τ^2 approaches infinity unless n is at least 4. A safer prior for τ^2 is:

$$p(\tau^2) = e^{-\tau^2}/(\tau/\sqrt{\pi}) \quad (4)$$

Usually, the actual variances of the estimates, σ_i^2, are not known and are replaced by their sample values.

Often the study parameter that varies is an effect measure, such as an odds ratio. This parameter then has two sources of variation: (1) the variation resulting from "mother nature" choosing different parameter values for each study and (2) the sampling variation from the study itself given a particular value from "mother nature." DerSimonian and Laird[2] give formulas for partitioning the variation in a random-effects model without making any particular distributional assumptions about the parameters. Let $\hat{\theta}_i$ be the estimate of the parameter, as before, and let w_i be the inverse of the sampling variance of $\hat{\theta}_i$. Define $\hat{\theta}_w$ as:

$$\hat{\theta}_w = \sum_{i=1}^{n} w_i\hat{\theta}_i \Big/ \sum_{i=1}^{n} w_i \quad (5)$$

Estimate τ^2 by:

$$\hat{\tau}^2 = \max\left\{0, [\hat{\theta}_w - (n-1)] \Big/ \left[\sum_{i=1}^{n} w_i - \left(\sum_{i=1}^{n} w_i^2 \Big/ \sum_{i=1}^{n} w_i\right)\right]\right\} \quad (6)$$

Now define v_i as $1/(1/w_i + \hat{\tau}^2)$. The estimate of θ is:

$$\hat{\theta} = \sum_{i=1}^{n} v_i\hat{\theta}_i \Big/ \sum_{i=1}^{n} v_i \quad (7)$$

and the variance of $\hat{\theta}$ is approximately:

$$\text{Var}(\hat{\theta}) \cong 1 \Big/ \sum_{i=1}^{n} v_i \quad (8)$$

Confidence Profile Method

The Confidence Profile Method is a very general method for combining virtually any kind of evidence about various parameters, as long as those parameters can be described in a model. The Confidence Profile Method can be used in either a Bayesian mode, to estimate a joint posterior distribution for the parameters of interest, or in a non-Bayesian mode, to estimate a joint likelihood function for the parameters of interest. The method will be applied to the special case where each study is estimating the same endpoint. The Confidence Profile Method uses a model that consists of three elements: (1) basic parameters, (2) functional parameters, and (3) likelihood functions relating evidence to basic or functional parameters. The description of these elements follows.

Basic Parameters. Basic parameters are those parameters that appear in the model that are not functions of any other parameters. For example, the respiratory disease rate in children living in homes with electric stoves in a particular study could be a basic parameter. For convenience, we will denote the basic parameters as $\theta_1, \theta_2, \ldots, \theta_k$. If a Bayesian analysis is to be used, then all basic parameters must have prior distributions. Noninformative priors for these parameters can be derived in a variety of ways. One standard method is to use a Jeffreys' prior.[7]

Functional Parameters. Each functional parameter, θ_j, is defined as a function of the basic parameters $\theta_1, \theta_2, \ldots, \theta_k$, and all previously defined functional parameters $\theta_{k+1}, \ldots, \theta_{j-1}$:

$$\theta = f_j(\theta_1, \theta_2, \ldots, \theta_{j-1}), j = k + 1, \ldots, m \quad (9)$$

Although the functions can be any mathematical expression, certain functions are very common. For example, the multiple logistic model is often used:

$$\theta_i = 1 \Big/ \left[1 + \exp\left(-\sum_{j=1}^{k} \beta_j x_{ij}\right)\right] \quad (10)$$

where the β_j's are logistic regression coefficients, the χ_{ij}'s are known constants and θ_i represents the probability that the i^{th} response is positive.

Likelihood Functions. Likelihood functions connect observed evidence to basic and functional parameters. For example, the likelihood function for a multiple logistic regression problem could be:

$$L(y|\beta_1, \beta_2, \ldots, \beta_k) \propto \prod_{i=1}^{n} \theta_i^{y_i}(1 - \theta_i)^{1-y_i} \quad (11)$$

where θ_i is defined in Equation 10 and where y_i equals 1 if the response is positive and equals zero otherwise. For a more complete discussion of likelihood functions, see Barnard and Sprout.[8]

The Model. Once the basic parameters, functional parameters, and likelihoods are defined, the model has been formulated. The general log-likelihood for the model (assuming independence of experiments) is:

$$LL = \sum_{s=1}^{S} \sum_{i=1}^{n_s} \ln L_{si}(Y_i|\theta_1, \ldots, \theta_m) \quad (12)$$

where i indexes the observations of an individual study, s

indexes the S different experiments, n_s is the number of observations in experiments S, and Y_i is the observed data for the i^{th} study. If priors have been defined, then the m dimensional posterior is defined as:

$$\pi(\theta_1, \ldots, \theta_m) = \left[\prod_{s=1}^{S}\prod_{i=1}^{nS} L_{si}(Y_i|\theta_1, \ldots, \theta_m)\right]\left[\prod_{j=1}^{k}\pi_j(\theta_j)\right] \quad (13)$$

Methods of Model Solution. There are five different methods for solving the model once it has been defined: (1) maximum likelihood estimation, (2) maximum likelihood methods for determining the posterior mode (3) exact solutions in certain special cases, (4) approximate solutions using moments, and (5) Monte Carlo simulation. The choice depends on the complexity of the model, the accuracy required, and the amount of computational power and time available. For additional discussion of these, see Eddy et al.[5] The Confidence Profile Method can be used for both fixed and random effects models.

An Application to Studies of Nitrogen Dioxide Effects on Respiratory Illness Symptoms

Lower respiratory tract illness (LRI) is one of the major causes of childhood morbidity in the United States.[9] This is of public health importance because childhood respiratory illness is extremely common and the potential for exposure to NO_2 is great.[10] Lower respiratory illness takes on added importance since recurrent childhood respiratory illness may be a risk factor for later susceptibility to lung damage.[10–13] Various studies of LRI have reported rates ranging from about 20 to 30 illnesses per 100 children in the first year of life.[9,14,15] The rate of LRI in children is affected by several factors that include age, immunologic status, prior viral infections, level of health, socioeconomic status, day care attendance,[16] environmental tobacco smoke (ETS), and exposure to NO_2 and other pollutants.

Bacteria are not thought to be common causes of LRI in nonhospitalized infants in the United States.[15] Seventy-five percent of the isolated microbes were one of four types: respiratory syncytial virus, parainfluenza virus Types 1 and 3, and M. pneumonia.[9,14] Early insult from virus infection in the lower respiratory tract is an essential element of the development of chronic and persistent impairment.[11–13] It is now recognized that infections, reactive airways, ETS, and other inhaled pollutants, are the most important risk factors in the development of chronic lung disease.[17] Thus, factors such as NO_2, which increase the risk for LRI, are important because of the associated public health concern and the potential for increase in the development of chronic lung disease.

Epidemiological studies of the relationship between NO_2 exposure and a health outcome such as LRI in children provide the majority of the evidence for examination of such relationships. Several factors arise in the interpretation of epidemiological studies of the health effects of NO_2: (1) measurement error in exposure, (2) misclassification of the health outcome, (3) selection bias, (4) adjustment for covariates, (5) publication bias, (6) internal consistency, and (7) plausibility of the effect based on other evidence.

The effect of measurement error on estimation has been studied by several authors, including Shy et al.,[18] Gladen and Rogan,[19] Stephanski and Carroll,[20] Fuller,[21] Schafer,[22] and Whittemore and Keller.[23] In general, measurement error that is independent of the health outcome will result in estimated effects biased towards the null. Whittemore and Keller[23] specifically consider the data of Melia et al.[24] as described by Florey et al.[25] and show that a 20 percent misclassification rate of the exposure category will result in an underestimate of the logistic regression coefficient by as much as 50 percent. Stefanski and Carroll[20] have shown that, even without the independence of error related to outcome, the bias is towards the null in situations where the risks are not extremely close to 0 or 1. The use of the presence of a gas stove as a surrogate for actual NO_2 exposure introduces misclassification.

Most studies of respiratory disease and NO_2 exposures measured the important covariates of age, gender, socioeconomic level of the parents, and parental smoking habits. The estimated effect (regression coefficient of disease on NO_2 exposure) will be an overestimate when a missing covariate is either positively or negatively correlated with both the exposure variable and the health outcome. The estimated effect will be an underestimate when a missing covariate is positively correlated with the exposure variable and negatively correlated with the health outcome, or vice versa. Ware et al.[26] found that parents with some college education were more likely to report respiratory symptoms and were less likely to use a gas stove, leading to an underestimate of the health effect if education were left out of the analysis.

Studies that examine NO_2 relationships to respiratory illness, when reviewed independently, produce somewhat mixed results.[27] The use of quantitative methods of synthesizing evidence presents the opportunity to examine the consistency between these studies and the strength of the total data base. Selected studies are discussed, followed by a combined analysis.

British Studies

Results of British studies have been reported by Melia et al.,[24,28–32] Goldstein et al.,[33,34] and Florey et al.[25,35] The initial study, reported by Melia et al.,[28] was based on a survey of 5,658 children (excludes asthmatics, thus 100 less than the number reported), aged 6 to 11 years, with sufficient information in 28 randomly selected areas of England and Scotland. The study included a self-administered, parent-completed questionnaire that obtained information on the presence of morning cough, day or night cough, colds going to chest, chest sounds of wheezing or whistling, and attacks of bronchitis. The questionnaire was distributed in 1973 and asked about symptoms during the previous 12 months. Colds going to chest accounted for the majority of the symptoms reported. Information about cooking fuel (gas or electric), age, gender, and social class (manual or nonmanual labor) was obtained, but information on parental smoking was not. No measurements of NO_2, either indoors or outdoors, were given. The authors presented their results in the form of a contingency table with complete covariate information for nonasthmatic children under age eight. The authors indicated that there was a trend for increased symptoms in homes with gas stoves, but that the increase was only significant for girls in urban areas; however, they did not report odds ratios or other measures of increased risk.

Our reanalysis of the authors' data was performed using a multiple-logistic model. Because it had been suggested that gender had an effect on the relationship with "gas cooker," interaction terms for gender were included in the original model. None of these proved to be significant, and they were subsequently dropped from the model. When separate terms for each gender were used for the effect of "gas cooker," an estimated odds ratio of 1.25 was obtained for boys and an odds ratio of 1.39 was obtained for girls, but the odds ratios were not significantly different. The combined odds ratio for both genders was 1.31 (95 percent confidence limits of 1.16 to 1.48) and was statistically significant from 1.00 ($p < .0001$). The other main effects of gender, socio-economic status, and age were all statistically significant.

Melia et al.[30] report further results of the national survey covering two groups: (1) a new cohort of 4,827 boys and

girls, aged 5 to 10 years, from 27 randomly selected areas who were examined in 1977 and (2) 2,408 children first examined in 1973 who were followed-up for at least one year and whose parents reported the use of the same cooking fuel for each year the child was studied. The 1977 study collected information on the number of smokers in the homes. In the 1977 cross-sectional study, only the prevalence of day or night cough in boys ($p \approx 0.02$) and colds going to chest in girls ($p < 0.05$) were found to be significantly higher in children from homes where gas was used for cooking compared with children from homes where electricity was used. Grouping responses according to the six respiratory questions into one or more symptoms or diseases, or none, yielded a prevalence higher in children from homes where gas was used for cooking than in those from homes where electricity was used ($p \approx 0.01$ in boys, $p = 0.07$ in girls). The authors examined the effect of gender, social class, use of pilot lights, and number of smokers in the homes.

Our reanalysis of the authors' data was performed applying a multiple-logistic model. This model contained the same terms that were included in our analysis of Melia et al.[28] As in the previous analysis, none of the interaction terms proved to be significant, and they were subsequently dropped from the model. The maximum likelihood estimate of the odds ratio was 1.24 (95 percent confidence limits of 1.09 to 1.42. This effect was statistically significant ($p < .0001$). The other main effects of gender, socioeconomic status, and age were all statistically significant.

This study was followed by a study in 1978 of 808 schoolchildren,[24] aged six to seven years, in Middlesborough, an urban area in northern England. Respiratory illness was defined in the same manner as in the previous study. Indoor NO_2 measurements were collected from 66 percent of the homes, with the remaining 34 percent refusing to participate. Nitrogen dioxide was measured by Palmes tubes[36] attached to walls in the kitchen areas and in children's bedrooms. In homes with gas stoves, levels of NO_2 in kitchens ranged from 10 to 596 $\mu g/m^3$ (0.005 to 0.317 ppm [1 $\mu g/m^3$ = 0.00053 ppm at 25°C, 760 mmHg]), with a mean of 211 $\mu g/m^3$; and levels in bedrooms ranged from 8 to 318 $\mu g/m^3$, with a mean of 56 $\mu g/m^3$. In homes with electric stoves, levels of NO_2 in kitchens ranged from 11 to 353 $\mu g/m^3$, with a mean of 34 $\mu g/m^3$, and in bedrooms NO_2 levels ranged from 6 to 70 $\mu g/m^3$, with a mean of 26 $\mu g/m^3$. Outdoor levels of NO_2 were determined using diffusion tubes systematically located throughout the area, and the weekly average ranged from 26 to 45 $\mu g/m^3$.

One analysis by the authors[24] was restricted to those 103 children in homes where gas stoves were present and where bedroom NO_2 exposure was measured. A multiple logistic regression model was fitted to the presence or absence of respiratory illness. Measured NO_2 exposure was found to be associated with respiratory illness, independent of social class, age, gender, or the presence of a smoker in the house ($p = 0.06$). However, when social class was excluded from the regression, the association was weaker ($p = 0.11$). For the six- to seven-year-old children living in gas stove homes, there appeared to be an increase of respiratory illness with increasing levels of NO_2 in their bedrooms ($p = 0.10$), but no significant relationship was found between respiratory symptoms in those children or their siblings or parents and levels of NO_2 in kitchens.

Since no exposure-response estimates were given by the authors, a multiple-logistic model was fitted to the data with a linear slope for NO_2 and separate intercepts for boys and girls. Nitrogen dioxide levels for the groups were estimated by fitting a lognormal distribution to the NO_2 data, which was reported by intervals, and the average exposures within each interval were estimated.[37] The estimated logistic regression coefficient for NO_2 (in $\mu g/m^3$) was 0.015 with a standard error of 0.007. This result is not directly comparable with the previous two analyses since it gives the increase in the logarithm of the odds of respiratory illness per unit increase in NO_2 exposure. Since most studies of gas stove exposure (both in the United States and the United Kingdom) show an approximate increase of 30 $\mu g/m^3$ in the NO_2 levels, the slope was multiplied by 30 to get the increase due to gas stove exposure, and then converted to an odds ratio by exponentiation. All of this assumed that the logarithm of the odds ratio was linear in NO_2 exposure. The result was an odds ratio of 1.53, with 95 percent confidence limits of 1.04 to 2.24.

The study was repeated January through March of 1980 by Melia et al.[31] This time, five- and six-year-old children were sampled from the same neighborhood as the previous study, but only families with gas stoves were recruited. Environmental measurements were made and covariate data were collected in a manner similar to the previous study. Measurements of NO_2 were available from 54 percent of the homes. The unadjusted rates of one or more symptoms by gender and exposure level were analyzed by the authors, and they concluded that "... no relation was found between the prevalence of respiratory illness and levels of NO_2." A reanalysis of the data was made using a multiple-logistic model similar to the one used for the previous study. The model included a linear slope for NO_2 and separate intercepts for boys and girls. Nitrogen dioxide levels for the groups were estimated by fitting a lognormal distribution to the grouped bedroom NO_2 data. The estimated logistic regression coefficient for NO_2 (in $\mu g/m^3$) was 0.004 with a standard error of 0.005. As for Melia et al.,[29] the regression coefficient was converted to an odds ratio for an increase of 30 $\mu g/m^3$ in NO_2 assuming that the logarithm of the odds ratio was linear in NO_2 exposure. This gave an odds ratio of 1.11, with 95 percent confidence limits of .83 and 1.49.

Melia et al.[32] investigated the association between gas cooking in the home and respiratory illness in a study of 390 infants born between 1975 and 1978. When a child reached one year of age, the child's mother was interviewed by a trained field worker who completed a questionnaire. The mother was asked whether the child usually experienced morning cough, day or night cough, wheeze, or colds going to chest, and whether the child had experienced bronchitis, asthma, or pneumonia during the past 12 months. No relation was found between the type of fuel used for cooking in the home and the prevalence of respiratory symptoms and diseases recalled by the mother after allowing for the effects of gender, social class, and parental smoking. The authors gave prevalence rates of children having at least one symptom by gas stove use and gender. The combined odds ratio for presence of symptoms by gas stove use was 0.63, with 95 percent confidence limits of 0.36 to 1.10.

United States Six-Cities Studies

Several authors[26,35–46] have reported on a series of studies conducted in six U.S. cities. The six cities were selected to represent a range of air quality based on their historic levels of outdoor pollution and included Watertown, Massachusetts; Kingston and Harriman, Tennessee; southeast St. Louis, Missouri; Steubenville, Ohio; Portage, Wisconsin; and Topeka, Kansas. Approximately 1,500 grade-school children were enrolled in each community and were followed for several years. Families reported the number of persons living in their homes and their smoking habits, parental occupations and educational backgrounds, and fuels used for cooking and heating. Outdoor pollution was measured at fixed sites in the communities and at selected households. Indoor pollution, including NO_2, was measured in several rooms of selected households. Results of monitoring in Portage, Wisconsin, verify that the presence of a gas stove contributes dramatically to indoor NO_2 levels.

The results clearly show the effect of a gas stove on not only the indoor concentrations but also on the personal exposure of the individual. The study[42] was conducted very carefully with excellent quality control. It gave an average estimate of 29 $\mu g/m^3$ increase in exposure resulting from the use of gas stoves in cities studied in the United States.

Ware et al.[26] reported results from the six-cities studies based on 8,120 children, aged 6 to 10 years, who were followed from 1974 to 1979. An initial report on a subset of the data was given by Speizer et al.[39] Health endpoints were measured by a standard respiratory questionnaire that was completed by parents of the children. The authors used log-linear models to estimate the effect of gas stoves versus electric stoves on the rates of serious respiratory illness before age two. Directly standardized rates of reported illnesses and symptoms did not show any consistent pattern of increased risk for children from homes with gas stoves. Logistic-regression analyses controlling for age, gender, city, and maternal smoking level gave estimated odds ratios for the effect of gas stoves ranging from 0.93 to 1.07 for bronchitis, cough, wheeze, LRI index, and illness for the past year. The index for LRI was defined as the presence of either bronchitis, respiratory illness that kept the child home three days or more, or persistent cough for three months of the past year. None of these odds ratios were statistically different from 1. Only two odds ratios approached statistical significance: (1) history of bronchitis (odds ratio = 0.86, 95 percent confidence interval 0.74 to 1.00) and (2) respiratory illness before age two (odds ratio = 1.13, 95 percent confidence interval 0.99 to 1.28). When the odds ratio for respiratory illness before age two was adjusted for parental education, the odds ratio was 1.11, with 95 percent confidence limits of 0.97 to 1.27 ($p = 0.14$). Thus, the study suggests an increase in respiratory illness of about 11 percent, although the increase was not statistically significant at the 0.05 level. The endpoint in the Ware et al.[26] study most similar to that of the Melia studies was the LRI index. The authors gave the unadjusted rates, and from those an estimated odds ratio of 1.08, with 95 percent confidence limits of 0.97 to 1.19, were calculated. Although this rate was not adjusted for other covariates, the effect of those adjustments on other endpoints was minimal.

Neas et al.[45,46] studied a cohort of 6,273 children from the same six cities. This cohort included children that were part of the Dockery et al.[44] analysis but was restricted to white children 7 to 11 years of age with complete covariate information and at least one valid indoor measurement of both NO_2 and respirable particles. This resulted in 1,286 children being included in the analysis. Methods for measuring indoor pollutants were described by Spengler et al.[38] Indoor pollutants were measured in each child's home for two weeks during the heating season and two weeks during the cooling season. Nitrogen dioxide was measured by Palmes tubes at three locations in each home.

The analysis of the Neas et al.[45,46] study was based on the third symptom questionnaire that was completed by parents following the indoor measurements. The questionnaire reported symptoms during the previous year, including shortness of breath, chronic wheeze, chronic cough, chronic phlegm, and bronchitis. The authors used a multiple-logistic model, which had separate-city intercepts, indicator variables for gender and age, parental history of chronic obstructive pulmonary disease and asthma, parental education, and single-parent family status. The sampling strategy minimized the association between NO_2 and passive-smoking exposure. The increases in symptoms were estimated for an additional 31 $\mu g/m^3$ NO_2 exposure. This corresponded to the average difference in NO_2 concentrations monitored in homes with a gas stove with a pilot light, based on exposure information from the study. Table I shows the odds ratios for the five separate symptoms associated with the increase in NO_2 exposure.

Table I. Odds ratios and 95 percent confidence intervals for the effect of an additional 31 $\mu g/m^3$ nitrogen dioxide on the symptom prevalence.

Symptom	Odds Ratio	95% Confidence Interval
Shortness of breath	1.27	0.92 to 1.73
Chronic wheeze	1.19	0.87 to 1.61
Chronic cough	1.21	0.86 to 1.71
Chronic phlegm	1.29	0.93 to 1.79
Bronchitis	1.05	0.71 to 1.56
Combined symptoms score	1.47	1.17 to 1.86

Source: Neas et al.[45]

All of these odds ratios are consistent with the size of effect seen in the other analyses of the six-city data and the analyses of the British studies. The authors defined a combined symptom, which was the presence of one or more of the symptoms just reported, and an analysis of this combined indicator of respiratory symptoms gave an estimated odds ratio of 1.47, with a 95 percent confidence interval of 1.17 to 1.86. When split by gender, the odds ratio was higher in girls, and when split by smoking and nonsmoking homes, it was higher in smoking homes.

Tayside Study

Ogston et al.[47] studied infant mortality and morbidity in the Tayside region of northern Scotland. The subjects were 1,565 infants born to mothers who were living in Tayside in 1980. Episodes of respiratory illness were recorded during the first year of life. The information was supplemented by observations made by a health visitor and scrutinized by a pediatrician who checked diagnostic criteria and validity. One health endpoint assessed was defined as the presence of any respiratory illness during the year. This endpoint was analyzed by the authors using a multiple-logistic regression model that included terms for parental smoking, age of mother, and presence of a gas stove. The estimated odds ratio for the presence of a gas stove was 1.14, with 95 percent confidence limits of 0.86 to 1.50. Only the coefficient for parental smoking was statistically significant ($p < 0.01$).

Iowa Study

Ekwo et al.[48] surveyed 1,355 children 6 to 12 years of age for respiratory symptoms and lung function in the Iowa City School District. Parents of the school children completed a questionnaire that was a modification of the questionnaire developed by the American Thoracic Society.[49] Eight different measures of respiratory illness were reported by the authors, but only the endpoint of chest congestion and phlegm with colds was similar to the endpoints used in the British studies and the six-city studies. Information on parental smoking was obtained and used as a covariate in the analysis. The result of the analysis, which was based on 1,138 children, was an odds ratio of 1.10 for gas stove use. The 95 percent confidence limits of 0.79 and 1.53 were derived from the authors' data. No NO_2 concentrations, either inside or outside the homes, were reported.

Dutch Studies

In the Netherlands, Houthuijs et al.,[50] Brunekreef et al.,[51] and Dijkstra et al.[52] studied the effects of indoor factors on respiratory health in children. The population

consisted of 6- to 9-year-old children from 10 primary schools in five nonindustrial communities in the southeast region of the Netherlands. Personal exposure to NO_2 and home concentrations were measured. An important NO_2 emission and exposure source in these homes are geysers, which are unvented gas-fired hot water sources at the water tap. Exposure to tobacco smoke was assessed with a questionnaire that also reported symptom information. Pulmonary function was measured at school. The study used Palmes tubes to measure a single weekly average personal NO_2 exposure. Potential high peak exposures from the geysers may not be well characterized by the weekly average personal exposure measurements. In January and February of 1985, the homes of 593 children who had not moved in the last four years were measured for one week for NO_2. Personal exposure was also estimated from time budgets and room monitoring.

Three measures of health (cough, wheeze, and asthma) were obtained from the questionnaire, which was a modified form of the World Health Organization questionnaire.[53] Asthma was defined as attacks of shortness of breath with wheezing in the last year. The presence of any of the three symptoms was used as a combination variable, and a logistic-regression model was used to fit the combination variable. Exposure was estimated by fitting a lognormal distribution to the exposure data, which was reported in intervals; and the mean exposure values for each group were estimated by a maximum likelihood technique.[37] The estimated logistic-regression coefficient was -0.002, corresponding to an odds ratio of .94 for an increase of 30 $\mu g/m^3$ in NO_2, with 95 percent confidence limits of 0.66 to 1.33. This assumed a linear relationship between the logarithm of the odds ratio and the NO_2 exposure. The rates were not adjusted for covariates such as parental smoking and age of the child.

Ohio Study

Keller et al.[54] and Mitchell et al.[55] originally conducted a 12-month study of respiratory illness and pulmonary function in families in Columbus, Ohio, prior to 1978. The study measured NO_2 exposure by both the Jacobs-Hochheiser and continuous-chemiluminescence methods. The electric stove users averaged 38 $\mu g/m^3$ NO_2 exposure, whereas the gas stove users averaged 94 $\mu g/m^3$. Thus, the estimated average difference between gas and electric stove use was 58 $\mu g/m^3$. The paper did not report which rooms were measured in order to get these averages. In a second related study,[56] 580 persons drawn from households that participated in the earlier study were examined to confirm the reports and to determine the frequency distribution of reported symptoms among parents and children in gas or electric stove homes. A nurse-epidemiologist examined selected persons who were reported ill. Unfortunately, these rates were not adjusted for other covariates. The percentage of children having lower respiratory symptoms in homes with a gas stove was 53.2 percent (n = 267) and 50.7 percent (n = 286) in homes with electric stoves. Although the difference is not statistically significant, these rates give an estimated odds ratio of 1.10, with 95 percent confidence limits of 0.74 to 1.54.

Synthesis of the Evidence

In order to combine the studies just described, several assumptions were necessary. First, although each study used a slightly different health outcome as an endpoint, we assumed that the endpoints are similar enough to warrant their combination. Second, the exposure levels were different in each study. An increase of 30 $\mu g/m^3$ was used as a standard increase, and all studies were used to estimate the effect of an increase of 30 $\mu g/m^3$, even if they had a different exposure range. Third, we assumed that each study controlled for key covariates, or that those covariates were properly adjusted for or are of minimal significance. The omission of covariates such as parental education almost certainly biases the results towards the null, and for this reason we retained some studies, which arguably could have been excluded.

The studies described used different indicators to study health endpoints. The symptoms describing LRI evaluated in the studies varied but are, in general, reasonable indicators of LRI. They include colds going to chest, chronic wheeze and cough, bronchitis, chest cough with phlegm, episodes of respiratory illness, and various respiratory indexes, which are combinations of more than one of these symptoms. These symptoms are comparable to indicators of LRI in children that were used in other studies. In order to compare these studies on respiratory effects of NO_2, a common endpoint was defined, and then each study was compared with this standard endpoint. The endpoint was the presence of reported LRI symptoms in children age 12 or younger.

An attempt was made to include as many studies as possible. The requirements for inclusion were (1) the health endpoint measured must be reasonably close to the standard endpoint; (2) exposure differences must exist, and some estimate of exposure (either direct or indirect) must be available; and (3) an odds ratio for a specified exposure must have been calculated, or data presented so that it can be calculated. These studies are summarized in Table II.

The approximate likelihoods for each study are shown in Figure 1. Each curve can be treated as a likelihood function or posterior-probability distribution. If treated as a likelihood function, then 95 percent confidence limits for the odds ratio can be calculated as those two points on the horizontal axis between which 95 percent of the area under the curve is contained. If treated as a posterior-probability distribution, then the area under the curve between any two points is the probability that the odds ratio lies between those two points. Note that all 11 likelihoods show some overlap. A chi-square goodness-of-fit test of the homogeneity of the 11 studies gives a chi-square of 18.75 with 10 degrees of freedom ($p = 0.0436$), suggesting some lack of homogeneity in the 11 studies.

The studies were combined using four methods: (1) the variance-weighted method, assuming a fixed-effects model; (2) the Confidence Profile Method, assuming a fixed-effects model; (3) the DerSimonian and Laird method, assuming a random-effects model; and (4) the Confidence Profile Method, assuming a random-effects model. Results of the use of these models in synthesizing the NO_2 evidence are presented in Table III for four subsets of the studies. The first includes all 11 studies; the second excludes the two studies on children less than one year of age; the third excludes the younger children and those studies that did not measure NO_2 directly; and the fourth excludes the younger children and those studies that measured NO_2 directly.

The results from all analyses are reasonably similar. The variance-weighted method and the Confidence Profile Method have identical answers because the log normal approximation for the likelihood function was used in the calculation of the solution by the Confidence Profile Method. In general, the results should be nearly identical for reasonable sample sizes. The DerSimonian and Laird[2] method and Confidence Profile Method[5] for the analysis of a random-effects model gave similar but not identical results.

Table II. Summary of the results of the effects of nitrogen dioxide exposure on respiratory disease in children.

Authors	Where/When	NO_2 Exposure Measure Used in Analysis	Age (years)	Sample Size	Odds Ratio for Respiratory Disease	95% Confidence Limits
Melia et al.[28]	28 areas of England and Scotland (1973)	Gas stove vs. electric stove.	6–11	5,658	1.31	1.16 to 1.48
Melia et al.[30]	27 areas of England and Scotland (1977)	Gas stove vs. electric stove.	5–10	4,827	1.24	1.09 to 1.42
Melia et al.[24] Florey et al.[25] Goldstein et al.[33]	Middlesborough, England (1978)	NO_2 measured with Palmes tubes.	6–7	103	1.53	1.04 to 2.24
Melia et al.[31]	Middlesborough, England (1980)	NO_2 measured with Palmes tubes.	5–6	188	1.11	0.83 to 1.49
Melia et al.[32]	London (1975 to 1978)	Gas stove vs. electric stove.	<1	390	0.63	0.36 to 1.10
Ware et al.[26]	Six U.S. cities (1974–1979)	Gas stove vs. electric stove.	6–10	8,240	1.08	0.96 to 1.37
Neas et al.[45]	Six U.S. cities (1983–1986)	NO_2 measured with Palmes tubes.	7–11	1,286	1.47	1.17 to 1.86
Ogston et al.[47]	Tayside region, Scotland (1980)	Gas stove vs. electric stove.	<1	1,565	1.14	0.86 to 1.50
Ekwo et al.[48]	Iowa City, Iowa	Gas stove vs. electric stove.	6–12	1,138	1.10	0.79 to 1.53
Dijkstra et al.[52] Brunekreef et al.[51]	Netherlands (1986)	NO_2 measured with Palmes tubes.	6–12	775	0.94	0.66 to 1.33
Keller et al.[54,56]	Columbus, Ohio (1978)	Gas stove vs. electric stove.	<12	553	1.10	0.74 to 1.54

The analysis of the nine studies with children 5 to 12 years old was done separately because the other two studies were of infants. The exclusion of these two studies made little difference in the results.

All studies that used the presence of a gas stove as a surrogate for NO_2 exposure obviously suffer from measurement error. In general, measurement error will decrease the estimated effect. When the four studies of children over age 5 years with measured NO_2 levels were combined, the estimated odds ratio did increase from about 1.18 to about 1.27. Thus there is some reason to believe that the use of a surrogate for exposure did bias the estimated effect, but the confidence limits of all estimates overlap significantly.

The evidence for effects on respiratory illness in children under age 12 is clearly very strong. All but one of the studies used in the synthesis showed increased respiratory illness rates associated with increased exposure. A few of the individual studies were statistically significant. When combined, the studies indicated that an increase of 30 $\mu g/m^3$ in NO_2 exposure would result in an increase of about 20 percent in respiratory illness, subject to the assumptions made for the synthesis. This result is not dependent on the

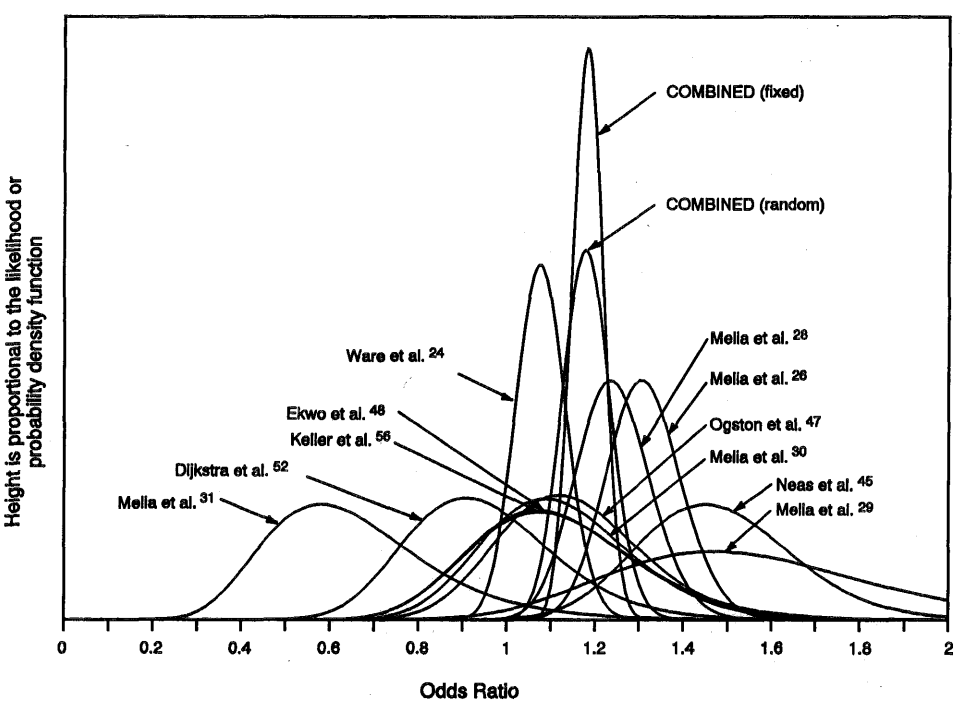

Figure 1. Meta-analysis of epidemiologic studies of 30 $\mu g/m^3$ nitrogen dioxide exposure increase on respiratory illness in children ≤ 12 years old.

TABLE III. Summary of synthesis of studies on respiratory illness effects of nitrogen dioxide.

Studies	Model-Method: Fixed — Variance-Weighted Method[6]	Model-Method: Fixed — Confidence Profile Method[5]	Model-Method: Random — DerSimonian and Laird[2]	Model-Method: Random — Confidence Profile Method[5]
All 11 studies	1.18 (1.11, 1.25)[a]	1.18 (1.11, 1.25)	1.18 (1.08, 1.30)	1.18 (1.08, 1.29)
Children aged 5–12 years, 9 studies	1.19 (1.12, 1.27)	1.19 (1.12, 1.27)	1.19 (1.09, 1.30)	1.20 (1.10, 1.31)
Measured NO_2, children aged 5–12 years, 4 studies	1.27 (1.09, 1.47)	1.27 (1.09, 1.47)	1.27 (1.02, 1.58)	1.25 (0.99, 1.58)
Surrogate NO_2 estimate based on presence of gas stove, children aged 5–12 years, 5 studies	1.18 (1.10, 1.26)	1.18 (1.10, 1.26)	1.18 (1.07, 1.29)	1.18 (1.09, 1.28)

[a]95% confidence limits given in parentheses.

results of any single study. Furthermore, the estimated effect is likely to be an underestimate, given the problems of misclassification of exposures and outcomes.

Discussion

The use of meta-analysis is becoming more common in the medical literature,[57] but is not common in environmental assessments. The ability to estimate a small but meaningful change in the risk of a health outcome measure from a single study may be difficult. Individual studies may not provide an accurate estimate of a potential risk. But the accuracy may be greatly improved by analyzing the total evidence from all studies simultaneously, that is, by conducting a meta-analysis. A potential limitation of a meta-analysis is that the studies available for use may represent a spectrum of quality. Well executed studies may be mixed with studies containing flaws—studies with missing data of confused definitions and outcome measures. On the other hand, such problems may be slight compared to problems with alternative traditional reviews. Meta-analysis fills a need by assisting in the reconciliation of conflicting research results. While some physical sciences may allow the identical replication of experiments, many fields such as environmental science allow only the repetition of studies that introduce variation and produce uncertainty. Meta-analysis is one way of dealing with uncertainty.

All meta-analysis methods previously discussed assume that each piece of evidence (study) is independent of the others. Under the fixed-effects model, the evidence is assumed to pertain to a common parameter. Under the random-effects model, this assumption is relaxed to allow for a distribution for the parameter of interest. The computations for both models are relatively straightforward and can be made on a personal computer. The method of calculation has less impact on the conclusion than does the choice of model.

In *Air Quality Criteria for Oxides of Nitrogen,* prepared 10 years ago by U.S. EPA,[58] a group of studies examining the relationship between respiratory illness and exposure in the home to gas combustion products from cooking fuel were evaluated. At that time, those studies inferred the presence of NO_2 by the presence of gas combustion emission sources. The evidence from individual studies of the effect of NO_2 on respiratory illness was somewhat mixed. Since then, new studies have been conducted, and earlier ones updated, that provide data on NO_2 concentrations and estimates of exposure.

The studies of respiratory illness in children exposed to increased levels of NO_2 provides an excellent example of the application of meta-analysis. Taken by themselves, most of the 11 studies were reported as not being statistically significant at the 0.05 level based on analyses performed by the original authors. The studies differed in design and sample size, and this likely contributed to the lack of significance of some of the studies. However, use of the meta-analysis methods described above indicates that, taken as a whole, the collective evidence from the evaluated studies strongly suggests an increase of at least 20 percent in the odds of respiratory illness in children exposed to an increase of 30 $\mu g/m^3$ NO_2 for extended periods of time.

The choices of model (fixed or random) and computational method make little difference in the estimates in this particular example. In particular, the estimates do not depend strongly on the assumption that each study is estimating the same parameter. Thus, any lack of homogeneity is not a major concern. The choice of the computational method (e.g., DerSimonian and Laird[2] versus the Confidence Profile Method[5]) also makes little difference in the estimates when restricted to the particular problem described in this paper. The Confidence Profile Method can be applied to a much broader class of problems, however.

There is always the concern that the studies described are not the complete list of studies, but contain primarily the positive studies, since these are the studies most likely to be published. This is referred to as "publication bias." There are two reasons not to be concerned with publication bias in this particular situation. First, prospective epidemiological studies are very expensive and require the work of many individuals. The studies are usually described to the scientific community before the results are even known. Second, most of the studies cited were reported as negative studies by the authors themselves, indicating that there was no difficulty in publishing negative results. In spite of this, it is of interest to contemplate an undiscovered study with results so negative that, when combined with the other studies, produces a confidence interval for the odds ratio that includes the value 1. If we assume that the hypothetical study is the size of the Ware et al.[26] study, then its odds ratio for increased respiratory symptoms as the result of a 30 $\mu g/m^3$ exposure would have to be 0.766.

Although there may be reasons to weight certain studies or groups of studies more heavily than others, the final conclusion has to be that there is an increase in the odds of respiratory illness of children, especially those of elementary-school age. The estimates are generally centered about an

odds ratio of 1.2, with 95 percent confidence limits of 1.1 to 1.3, although the studies using measured NO_2 give a slightly higher estimate of the odds ratio. This kind of synthesis may be possible for other areas of environmental assessment where multiple studies of a given health endpoint are available.

Acknowledgment

The authors thank the members of the Oxides of Nitrogen Workshop Review Group for their suggestions that lead to this paper. The authors also thank James Ware, Lucas Neas, and Jonathan Samet for their advice. Finally, the authors thank the Journal's reviewers whose suggestions added greatly to the paper. The views expressed in this paper are those of the authors and do not necessarily reflect the views or policies of the U.S. Environmental Protection Agency.

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Gas infrastructure in Mass.: A recipe for disaster?

JESSICA RINALDI/GLOBE STAFF

Columbia Gas workers worked on pipes off of Parker Street in South Lawrence on Sept. 20.

By Kay Lazar and Jon Chesto GLOBE STAFF **SEPTEMBER 22, 2018**
https://www.bostonglobe.com/metro/2018/09/22/recipe-for-disaster/ooDZkPJSsSmO8l6KIUDcjO/story.html

An underground labyrinth of leak-prone, corroding natural gas pipes. Mounting pressure on utilities to upgrade ancient infrastructure. A chronic shortage of trained workers. And a surge of retirements among state inspectors.

This is the backdrop for the natural gas fires and explosions that rocked the Merrimack Valley Sept. 13.

The gas lines that wend throughout the state, beneath city streets, and into people's homes are overseen by a patchwork of bureaucracies and a regulatory system that largely trusts utility companies to police themselves.

Though such calamities are rare, safety experts and local leaders say the gas industry needs more rigorous, transparent oversight to avoid more disasters.

"Is the inspection and regulatory system adequate? We would say, 'No, there are not enough inspectors looking at things often enough,' but it goes deeper than that," said Carl Weimer, executive director of the Pipeline Safety Trust, a Washington nonprofit that researches and advocates for pipeline safety.

Just weeks before the Merrimack Valley explosions, federal pipeline regulators audited the state's utility commission and raised concerns about attrition among the agency's inspectors. At the time, the state had just two engineers doing field inspections of pipeline work.

While the Massachusetts Department of Public Utilities received high marks, the Pipeline and Hazardous Materials Safety Administration auditor noted that with so few inspectors in the field, the state was likely to fall behind in inspections of gas work.

One person died, dozens were injured, and about 8,600 customers were left without service in the explosions that occurred while crews for Columbia Gas were working on replacing older, leak-prone pipes in Andover, North Andover, and Lawrence.

Investigators say it will take months to know precisely what went wrong, but the National Transportation Safety Board said preliminary evidence indicates pressure levels were well above normal at the time of the blasts.

With regulators now scrutinizing Columbia Gas operations, safety experts say federal rules too often give utility companies a wide berth, leaving consumers vulnerable.

Weimer, of the Pipeline Safety Trust, said gas companies have too much "wiggle room" to develop plans for mitigating risks in their own systems.

"There are all these standards written by the industry that are then incorporated in the regulations, and that's a real problem," Weimer said. "It's a rush to the bottom of what the industry will agree to."

The Department of Public Utilities noted that federal laws place responsibility for regular pipeline inspections with the utility companies themselves.

Meanwhile, a slew of departures from the department raises questions about its oversight capabilities.

State Representative Lori Ehrlich, a Marblehead Democrat who has sponsored legislation that requires gas companies to classify and address leaks, expressed skepticism about the DPU's oversight. She said she tried, without luck, to reach someone at DPU last week to talk about pipeline safety.

"There are 21,000 miles of pipeline" distributing gas to customers around Massachusetts, she said. "That's a lot of pipeline for two people to cover."

JESSICA RINALDI/GLOBE STAFF

Gas workers tended to pipes off of Brookfield Street in South Lawrence earlier this month.

Data from the state comptroller show eight DPU inspectors have retired in the past three years — including four since March. That left the agency with just two doing field work at the time of the federal inspection in August, according to the Pipeline and Hazardous Materials Safety Administration audit.

The DPU conducted 1,170 "on-site inspections" in 2017, up from 716 in 2013, according to records provided by the department.

State officials said six engineers were certified to conduct pipeline inspections at the time of the most recent federal audit, but one was out on medical leave, another was working on desk-bound duties due to medical issues, and two were working as supervisors.

DPU spokesman Peter Lorenz said six of the state's eight public utility engineers are certified to conduct pipeline inspections in the field, although one still serves as a supervisor, and two more engineers will become certified in the near future. DPU is also in the process of hiring a ninth public utility engineer.

The level of staffing has been a sore spot for the two unions that represent some 1,250 gas workers who have been locked out of National Grid work sites amid a contractual dispute.

John Buonopone, president of the United Steelworkers Local 12012, said he testified at the State House five years ago about the need for more field inspectors at DPU, and has raised it with the agency since the lockout began.

"The state will say they have eight inspectors but . . . they really only have three [doing field inspections] in the best of times," Buonopone said. "With all the work they have going on, there should be between 50 and 100 field inspectors."

Susan Tierney, a former state DPU commissioner who now works as a consultant in the energy field, said it wouldn't surprise her if the agency cut back on pipeline inspection staffing in recent years because there hasn't been a major incident to raise concerns. That's a typical approach, she said, for a utility regulator.

Following the Merrimack Valley explosions, the DPU called in reinforcements: three inspectors from New Hampshire and two from Pennsylvania.

The budget for the DPU's pipeline safety division has grown in recent years — it's now at $2.8 million — although the majority of its funding comes from the federal government.

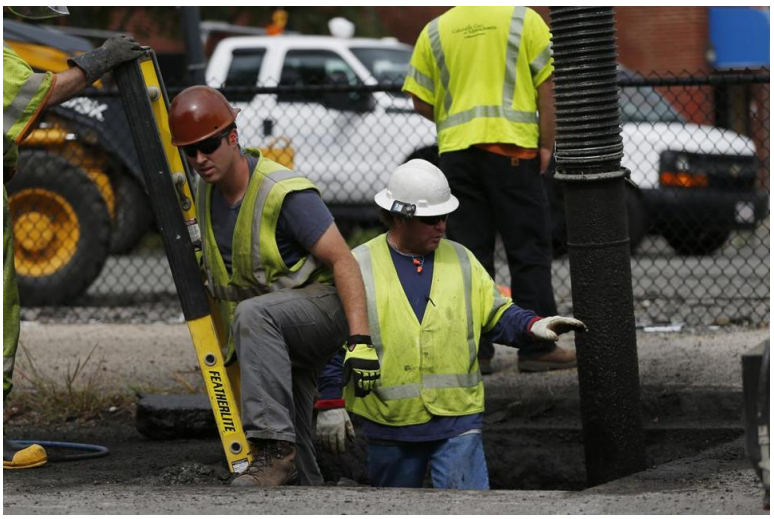
Nationwide, there are roughly 2.2 million miles of gas distribution lines similar to the ones in the Merrimack Valley. Most state oversight agencies do not have the staffing for regular site visits, which is why federal rules place responsibility with gas companies for routine inspections, according to the American Gas Association, an industry trade group.

"A state inspector may come out and look at the operations manual. But they do not go out and inspect the line itself. That's the responsibility of the operator," said Lori Traweek, the association's chief operating officer.

"The operators have as much interest as anyone to make sure their pipelines are safe and they meet the specifications as required, and they are complying with regulations," Traweek said.

While dramatic explosions such as the recent inferno in the Merrimack Valley often make headlines, Traweek noted that most incidents involving gas lines are not the fault of gas companies but rather occur because of damage caused during construction projects, such as a backhoe hitting a gas line.

Perhaps the most infamous recent natural gas pipeline disaster was the explosion that killed eight people and leveled part of a neighborhood in 2010, in San Bruno, Calif.



JESSICA RINALDI/GLOBE STAFF

Columbia Gas workers worked on pipes off of Parker Street in South Lawrence.

Nick Stavropoulos, a longtime Massachusetts utility executive, was recruited by the California utility PG&E to help with the company's multi-billion-dollar recovery efforts.

Stavropoulos, now utility president at PG&E, said his team accelerated the company's pipeline replacement program, removing all of the cast iron pipes that were at risk of being compromised and replacing them with plastic. And the company invested tens of millions of dollars in training.

California's public utilities department also stepped up its efforts, adding more inspectors and conducting more frequent audits. Stavropoulos said PG&E valued the extra scrutiny.

"By increasing the intensity of their audits and inspections, we think they've been a really important party to reduce risk on our system and improve the safety of our operations," Stavropoulos said.

Federal data from the Pipeline and Hazardous Materials Safety Administration show that over the past decade 29 percent of significant incidents nationwide are from excavations, while only 9 percent are linked to operator error.

But in Massachusetts, a significantly higher percentage of incidents are traced to operator error: 19 percent.

These incidents come as gas companies nationwide face significant hurdles in their race to upgrade the nation's leaky pipelines. A 2017 report from the US Department of Energy noted "limited workforce capacity and training availability for federal and state pipeline safety inspectors."

It said the federal government's Office of Pipeline Safety operates a single gas and hazardous material training facility for the entire nation, and the federal certification process for state inspectors can extend up to five years. It found a one-to-two-year backlog for admission to the federal government's state inspector training program.

The report also noted that pipeline upgrades require skilled laborers with the required certification.

"These resources are limited in most parts of the country," it concluded. "The shortage of qualified labor has been exacerbated in some areas that have a significant share of the total leak prone pipe inventory, such as the Mid-Atlantic and Northeast, as multiple states and companies are now focusing on pipeline repair and replacement."

This panoply of looming problems, coupled with the spectacular eruptions in the Merrimack Valley, worries Boston City Councilor Matt O'Malley, who has called for a public hearing to examine the safety of natural gas pipelines in the city.

"I don't want to suggest that folks should be panicked, but I think we should all be concerned that what happened in the Merrimack Valley can happen anywhere," he said. "It underscores my deep concern that such little information is shared with municipalities from utility companies."

JESSICA RINALDI/GLOBE STAFF

A gas worker took a break on Brookfield Street in South Lawrence.

Matt Rocheleau of the Globe staff contributed to this report. Kay Lazar can be reached at kay.lazar@globe.com Follow her on Twitter @GlobeKayLazar.

Jon Chesto can be reached at jon.chesto@globe.com . Follow him on Twitter @jonchesto.

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Home Energy Efficiency Team

MOTHERS OUT FRONT
MOBILIZING FOR A LIVABLE CLIMATE

Gas is the Past!

Natural gas carries risks to our health and our planet

Cooking with gas can harm children

Cooking with gas releases fumes into your kitchen. Both unburned gas and burned (combusted) gas release toxic chemicals into the air in your home.

These chemicals include lead, chromium, benzene, hexane, formaldehyde, and nitrogen dioxide (NO_2).[1] All of these are harmful to human health.

Many people think that the vent over their stove is just for removing cooking odors, but it's actually very important to turn on the fan whenever cooking with gas to remove the toxic chemicals from the air in your home.

Using gas to cook makes children more susceptible to respiratory infections and worsens asthma, especially in homes that aren't properly ventilated.

Here's the research:

A nationally-representative study of US children described increased prevalence of asthma, chronic bronchitis, and wheezing among children whose parents reported using a gas stove without ventilation.[2]

A similar study found that the prevalence of pneumonia and coughing in younger children was higher in families who cooked and heated their homes with gas stoves.[3]

Another analysis of 41 studies found a 32% increased risk of asthma among children in homes where gas was used for cooking.[4]

Nitrogen dioxide is well studied, harmful to children, and significantly higher in homes with gas stoves.[5,6] In a combined analysis of 11 pediatric studies, researchers concluded that a long-term increase of 15 parts per billion of NO_2 (about the difference between cooking with gas versus electric) increased the risk of respiratory illnesses such as asthma by 20%.[7]

In Massachusetts, researchers also found a "dose-response" relationship between the amount of NO_2 exposure (the "dose") and the asthma severity of children (the "response"). The more NO_2, the worse the asthma.[8]

Fracking contaminates air & water

In Massachusetts, more than half of the gas we use is mined through hydraulic fracturing, also known as fracking.[9] Fracking contaminates local air and water.

Living near a fracking site is associated with higher rates of asthma as well as premature and low birth-weight babies[10] who have long-term health risks and medical costs.

By reducing our consumption of gas, we can help protect these communities.

Why getting off of gas matters:

- Healthier kids
- Cleaner air and water
- A more livable, stable climate

heet
Home Energy Efficiency Team

MOTHERS OUT FRONT
MOBILIZING FOR A LIVABLE CLIMATE

"Natural" gas speeds up climate change

Here in New England, many of our homes use natural gas.[11] This gas is mostly methane, a potent greenhouse gas. Because a significant amount of that methane leaks into the atmosphere all along the system from where it's produced to where it's used, natural gas damages our climate more than coal.[12]

Switching from gas to electric appliances powered by clean, renewable energy is part of the solution!

Time to turn off the gas!

You can help make your home safer for your children, reduce air and water pollution from fracking, and be a part of the climate change solution.

- Always turn on your vent hood or open a window when you cook with gas.
- Use an inexpensive single or double burner induction cooktop instead of your gas stove. You can even place it on top of your gas burners, but remove the knobs so no one accidentally turns on the gas and melts it.
- Replace your gas stove with an electric or induction stove when you can.
- Plan to replace your gas or oil heat with an electric system when you can.

A well-designed study shows that replacing a gas stove with an electric one reduces indoor NO_2 levels.[13] Using ventilation can help too, but the same study found that vents were not as helpful at reducing NO_2 levels, probably because people tend to forget to turn on the vent.

Another Boston study found that replacing a gas stove with an electric one may create healthcare savings by reducing asthma-related hospital visits.[14]

Is an Induction Stove Right for You?

If you love the control of gas cooking, try an induction stovetop instead.

- The temperature control of induction is just as fine as gas but more consistent.
- Food cooks up to twice as fast.
- The stovetop is easier to clean.
- It is harder to burn yourself.
- There are no explosive gasses or toxic chemicals from gas in your kitchen.

Induction cooking is powered by electricity, not gas. **In Massachusetts, using an induction stove instead of a gas one cuts carbon emissions in half.** As we speed up our transition to more renewable energy, your emissions will decrease faster.

Make a Plan

Switching your house to all electric is part of the transition to using only clean, renewable energy. It can take time to move from gas to electric but it's worth the effort for your family's health and our climate. Make a budget and a timeline for switching to an induction or electric stove and an electric heat source when you can. Or be ready to make the switch when your old gas appliances break.

[1] Environmental Protection Agency (EPA). Natural Gas Combustion. www3.epa.gov/ttn/chief/ap42/ch01/final/c01s04.pdf (Last accessed November, 2017.)
[2] Kile ML, Coker ES, Smit E, Sudakin D, Molitor J, Harding AK. A cross-sectional study of the association between ventilation of gas stoves and chronic respiratory illness in U.S. children enrolled in NHANESIII. Environmental Health. 2014;13:71. doi:10.1186/1476-069X-13-71.
[3] Coker ES, Smit E, Harding AK, Molitor J, Kile ML. A cross sectional analysis of behaviors related to operating gas stoves and pneumonia in U.S. children under the age of 5. BMC Public Health. 2015;15:77. doi:10.1186/s12889-015-1425-y.
[4] Lin W, Brunekreef B, Gehring, U; Meta-analysis of the effects of indoor nitrogen dioxide and gas cooking on asthma and wheeze in children, International Journal of Epidemiology, 2013; 42(6): 1724-1737. doi:10.1093/ije/dyt150
[5] Belanger K, Gent JF, Triche EW, Bracken MB, Leaderer BP. Association of Indoor Nitrogen Dioxide Exposure with Respiratory Symptoms in Children with Asthma. American Journal of Respiratory and Critical Care Medicine. 2006;173(3):297-303. doi:10.1164/rccm.200408-1123OC.
[6] Belanger K, Holford TR, Gent JF, Hill ME, Kezik JM, Leaderer BP. Household levels of nitrogen dioxide and pediatric asthma severity. Epidemiology (Cambridge, Mass). 2013;24(2):320-330. doi:10.1097/EDE.0b013e318280e2ac.
[7] Hasselblad V1, Eddy DM, Kotchmar DJ. Synthesis of environmental evidence: nitrogen dioxide epidemiology studies. J Air Waste Manage Assoc. 1992 May;42(5):662-71.
[8] Belanger K, Holford TR, Gent JF, Hill ME, Kezik JM, Leaderer BP. Household levels of nitrogen dioxide and pediatric asthma severity. Epidemiology (Cambridge, Mass). 2013;24(2):320-330. doi:10.1097/EDE.0b013e318280e2ac.
[9] The US Energy Administration. Today in Energy. https://www.eia.gov/todayinenergy/detail.php?id=26112 Last accessed January, 2018.
[10] Stone, J. Fracking Is Dangerous to Your Health -- Here's Why. Forbes, Feb. 23, 2017. https://www.forbes.com/sites/judystone/2017/02/23/fracking-is-dangerous-to-your-health-heres-why/#41e5e41b5945 Last accessed November, 2017.
[11] Gas stoves are used by around 39% of US households. US Department of Housing and Urban Development and US Census Bureau, American Housing Survey for the United States. 2009. www.census.gov/prod/2011pubs/h150-09.pdf) Gas is used more widely in Northeast compared to other regions. https://www.eia.gov/todayinenergy/detail.php?id=18131
[12] The Union of Concerned Scientists. Environmental Impacts of Natural Gas. https://www.ucsusa.org/clean-energy/coal-and-other-fossil-fuels/environmental-impacts-of-natural-gas#.WlFv6FQ-fBI. Last accessed January, 2018
[13] Paulin LM, Diette GB, Scott M, et al. Home interventions are effective at decreasing indoor nitrogen dioxide concentrations. Indoor air. 2014;24(4):416-424. doi:10.1111/ina.12085.
[14] Fabian MP, Adamkiewicz G, Stout NK, Sandel M, Levy JI. A simulation model of building intervention impacts on indoor environmental quality, pediatric asthma, and costs. The Journal of allergy and clinical immunology. 2014;133(1):10.1016/j.jaci.2013.06.003. doi:10.1016/j.jaci.2013.06.003.

Board of Health

Kathleen Ward Brown, ScD
Member

Edward Cosgrove, PhD
Vice Chair

Stephen Epstein, MD, MPP
Chair

ARTICLE 1
Regulation Affecting Smoking and the Sale and Distribution of Tobacco Products in Needham

A. Statement of Purpose:

Whereas there exists conclusive evidence that tobacco smoking causes cancer, respiratory and cardiac diseases, negative birth outcomes, irritations to the eyes, nose and throat[1];

Whereas the U.S. Department of Health and Human Services has concluded that nicotine is as addictive as cocaine or heroin[2] and the Surgeon General found that nicotine exposure during adolescence, a critical window for brain development, may have lasting adverse consequences for brain development,[3] and that it is addiction to nicotine that keeps youth smoking past adolescence.[4]

Whereas a Federal District Court found that Phillip Morris, RJ Reynolds and other leading cigarette manufacturers "spent billions of dollars every year on their marketing activities in order to encourage young people to try and then continue purchasing their cigarette products in order to provide the replacement smokers they need to survive" and that these companies were likely to continue targeting underage smokers[5];

Whereas more than 80 percent of all adult smokers begin smoking before the age of 18, more than 90 percent do so before leaving their teens, and more than 3.5 million middle and high school students smoke;[6]

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[1] Center for Disease Control and Prevention, (CDC) (2012), *Health Effects of Cigarette Smoking Fact Sheet.* Retrieved from: http://www.cdc.gov/tobacco/data_statistice/fact_sheets/health_effects/effects_cig_smoking/index. htm.

[2] CDC (2010), *How Tobacco Smoke Causes Disease: The Biology and Behavioral Basis for Smoking-Attributable Disease.* Retrieved from: http://www.cdc.gov/tobacco/data_statistics/sgr/2010/.

[3] U.S. Department of Health and Human Services. 2014. *The Health Consequences of Smoking – 50 Years of Progress: A Report of the Surgeon General*. Atlanta: U.S. National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, p. 122. Retrieved from: http://www.surgeongeneral.gov/library/reports/ 50-years-of-progress/full-report.pdf.

[4] Id. *at* Executive Summary p. 13. Retrieved from: http://www.surgeongeneral.gov/library/reports/50-years-of-progress/exec-summary.pdf

[5] United States v. Phillip Morris, Inc., RJ Reynolds Tobacco Co., et al., 449 F.Supp.2d 1 (D.D.C. 2006) at Par. 3301 and Pp. 1605-07.

[6] SAMHSA, Calculated based on data in 2011 National Survey on Drug Use and Health and U. S. Department of Health and Human services (HHA).

Whereas 18.1 percent of current smokers aged <18 years reported that they *usually* directly purchased their cigarettes from stores (i.e. convenience store, supermarket, or discount store) or gas stations, and among 11th grade males this rate was nearly 30 percent ;[7]

Whereas the Institute of Medicine (IOM) concludes that raising the minimum age of legal access to tobacco products to 21 will likely reduce tobacco initiation, particularly among adolescents 15 – 17, which would improve health across the lifespan and save lives[8].

Whereas the 2014 MetroWest Adolescent Health Survey (MHAWS) results show that 8% of Needham high school students used cigarettes on at least one day of the 30 days before the survey, compared with 5% of students in 2012. And whereas the 2014 MetroWest Adolescent Health Survey (MHAWS) results show that 19% of Needham high school students used cigarettes in their lifetime, compared with 17% of students in 2012.[9]

Whereas cigars and cigarillos, can be sold in a single "dose;" enjoy a relatively low tax as compared to cigarettes; are available in fruit, candy and alcohol flavors; and are popular among youth[10];

Whereas research shows that increased cigar prices significantly decreased the probability of male adolescent cigar use and a 10% increase in cigar prices would reduce use by 3.4%[11];

Whereas 59% of high school smokers in Massachusetts have tried flavor cigarettes or flavored cigars and 25.6% of them are current flavored tobacco product users; 95.1 % of 12 – 17 year olds who smoked cigars reported smoking cigar brands that were flavored;[12]

Whereas the Surgeon General found that exposure to tobacco marketing in stores and price discounting increase youth smoking;[13]

Whereas the federal Family Smoking Prevention and Tobacco Control Act (FSPTCA), enacted in 2009, prohibited candy- and fruit-flavored cigarettes,[14] largely because these flavored products were marketed to youth and young adults,[15] and younger smokers were more likely to have tried these products than older smokers[16], neither federal nor Massachusetts laws restrict sales of flavored non-cigarette tobacco products, such as cigars, cigarillos, smokeless tobacco, hookah tobacco, and electronic devices and the nicotine solutions used in these devices;

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[7] CDC (2013) Youth Risk Behavior, Surveillance Summaries (MMWR 2014: 63 (No SS-04)). Retrieved from: www.cdc.gov.

[8] IOM (Institute of Medicine) 2015. *Public Health Implications of Raising the Minimum Age of Legal Access to Tobacco Products.* Washington DC: The National Academies Press, 2015.

[9] MetroWest Adolescent Health Survey: Needham High School Reports 2012 and 2014.

[10] CDC (2009), *Youth Risk Behavior, Surveillance Summaries* (MMWR 2010: 59, 12, note 5). Retrieved from: http:www.cdc.gov/mmwr/pdf/ss/ss5905.pdf.

[11] Ringel, J., Wasserman, J., & Andreyeva, T. (2005) *Effects of Public Policy on Adolescents' Cigar Use: Evidence from the National Youth Tobacco Survey.* American Journal of Public Health, 95(6), 995-998, doi: 10.2105/AJPH.2003.030411 and cited in *Cigar, Cigarillo and Little Cigar Use among Canadian Youth: Are We Underestimating the Magnitude of this Problem?*, J. Prim. P. 2011, Aug: 32(3-4):161-70. Retrieved from: www.nebi.nim.gov/pubmed/21809109.

[12] Massachusetts Department of Public Health, 2015 Massachusetts Youth Health Survey (MYHS); Delneve CD et al., Tob Control, March 2014: Preference for flavored cigar brands among youth, young adults and adults in the USA.

[13] U.S. Department of Health and Human Services. 2012. *Preventing Tobacco Use Among Youth and Young Adults: A Report of the Surgeon General*. Atlanta: U.S. National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, p. 508-530, *www.surgeongeneral.gov/library/reports/preventing-youth-tobacco-use/full-report.pdf*.

[14] 21 U.S.C. § 387g.

[15] Carpenter CM, Wayne GF, Pauly JL, et al. 2005. "New Cigarette Brands with Flavors that Appeal to Youth: Tobacco Marketing Strategies." *Health Affairs*. 24(6): 1601–1610; Lewis M and Wackowski O. 2006. "Dealing with an Innovative Industry: A Look at Flavored Cigarettes Promoted by Mainstream Brands." *American Journal of Public Health*. 96(2): 244–251; Connolly GN. 2004. "Sweet and Spicy Flavours: New Brands for Minorities and Youth." *Tobacco Control*. 13(3): 211–212; U.S. Department of Health and Human Services. 2012. *Preventing Tobacco Use Among Youth and Young Adults: A Report of the Surgeon General*. Atlanta: U.S. National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, p. 537, *www.surgeongeneral.gov/library/reports/preventing-youth-tobacco-use/full-report.pdf*.

[16] U.S. Department of Health and Human Services. 2012. *Preventing Tobacco Use Among Youth and Young Adults: A Report of the Surgeon General*. Atlanta: U.S. National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, p. 539, *www.surgeongeneral.gov/library/reports/preventing-youth-tobacco-use/full-report.pdf*.

Whereas the U.S. Food and Drug Administration and the U.S. Surgeon General have stated that flavored tobacco products are considered to be "starter" products that help establish smoking habits that can lead to long-term addiction;[17]

Whereas the U.S. Surgeon General recognized in his 2014 report that a complementary strategy to assist in eradicating tobacco related death and disease is for local governments to ban categories of products from retail sale;[18]

Whereas the U.S. Centers for Disease Control and Prevention has reported that the current use of electronic cigarettes, a product sold in dozens of flavors that appeal to youth, among middle and high school students tripled from 2013 to 2014;[19]

Whereas 5.8% of Massachusetts youth currently use e-cigarettes and 15.9% have tried them[20] and in Needham 17% of Needham high school students currently use e-cigarettes and 29% of those students have tried e-cigarettes once in their lifetime, according to the 2014 MetroWest Adolescent Health Survey (MHAWS).[21]

Whereas the Massachusetts Department of Environmental Protection has classified liquid nicotine in any amount as an "acutely hazardous waste";[22]

Whereas in a lab analysis conducted by the FDA, electronic cigarette cartridges that were labeled as containing no nicotine actually had low levels of nicotine present in all cartridges tested, except for one[23];

Whereas according to the CDC's youth risk behavior surveillance system, the percentage of high school students in Massachusetts who reported the use of cigars within the past 30 days is 10.8% in 2013; [24]

Whereas data from the National Youth Tobacco Survey indicate that more than two-fifths of U.S. middle and high school smokers report using flavored little cigars or flavored cigarettes;[25]

Whereas the sale of tobacco products is incompatible with the mission of health care institutions because these products are detrimental to the public health and their presence in health care institutions undermine efforts to educate patients on the safe and effective use of medication, including cessation medication;

Whereas educational institutions sell tobacco products to a younger population, who is particularly at risk for becoming smokers and such sale of tobacco products is incompatible with the mission of educational institutions that educate a younger population about social, environmental and health risks and harms;

Whereas the Massachusetts Supreme Judicial Court has held that " . . . [t]he right to engage in business must yield to the paramount right of government to protect the public health by any rational means"[26].

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[17] Food and Drug Administration. 2011. *Fact Sheet: Flavored Tobacco Products*, www.fda.gov/downloads/TobaccoProducts/ProtectingKidsfromTobacco/FlavoredTobacco/UCM183214.pdf; U.S. Department of Health and Human Services. 2012. *Preventing Tobacco Use Among Youth and Young Adults: A Report of the Surgeon General*. Atlanta: U.S. National Center for Chronic Disease Prevention and Health Promotion, Office on Smoking and Health, p. 539, www.surgeongeneral.gov/library/reports/preventing-youth-tobacco-use/full-report.pdf.

[18] *See* fn. 3 at p. 85.

[19] Centers for Disease Control & Prevention. 2015. "Tobacco Use Among Middle and High School Students — United States, 2011–2014," *Morbidity and Mortality Weekly Report (MMWR)* 64(14): 381–385;

[20] Massachusetts Department of Public Health, 2015 Massachusetts Youth Health Survey (MYHS)

[21] MetroWest Adolescent Health Survey: Needham High School Reports 2012 and 2014.

[22] 310 CMR 30.136

[23] Food and Drug Administration, *Summary of Results: Laboratory Analysis of Electronic Cigarettes Conducted by FDA*, available at: http://www.fda.gov/newsevents/publichealthfocus/ucm173146.htm.

[24] *See* fn. 7.

[25] King BA, Tynan MA, Dube SR, et al. 2013. "Flavored-Little-Cigar and Flavored-Cigarette Use Among U.S. Middle and High School Students." *Journal of Adolescent Health*. [Article in press], www.jahonline.org/article/S1054-139X%2813%2900415-1/abstract.

Now, therefore it is the intention of the Needham Board of Health to regulate the sale of tobacco products.

B. **Authority:**

This regulation is promulgated pursuant to the authority granted to the Needham Board of Health by Massachusetts General Laws Chapter 111, Section 31 which states that "Boards of health may make reasonable health regulations".

C. **Definitions:**

For the purpose of this regulation, the following words shall have the following meanings:

Adult-only retail tobacco store: An establishment that is not required to possess a retail food permit whose primary purpose is to sell or offer for sale but not for resale, tobacco products and tobacco paraphernalia, in which the sale of other products is merely incidental, and in which the entry of persons under the minimum legal sales age is prohibited at all times, and maintains a valid permit for the retail sale of tobacco products as required to be issued by the Needham Board of Health.

Blunt Wrap: Any tobacco product manufactured or packaged as a wrap or as a hollow tube made wholly or in part from tobacco that is designed or intended to be filled by the consumer with loose tobacco or other fillers regardless of any content.

Business Agent: An individual who has been designated by the owner or operator of any establishment to be the manager or otherwise in charge of said establishment.

Characterizing flavor: A distinguishable taste or aroma, other than the taste or aroma of tobacco, menthol, mint or wintergreen, imparted or detectable either prior to or during consumption of a tobacco product or component part thereof, including, but not limited to, tastes or aromas relating to any fruit, chocolate, vanilla, honey, candy, cocoa, dessert, alcoholic beverage, herb or spice; provided, however, that no tobacco product shall be determined to have a characterizing flavor solely because of the provision of ingredient information or the use of additives or flavorings that do not contribute to the distinguishable taste or aroma of the product.

Cigar: Any roll of tobacco that is wrapped in leaf tobacco or in any substance containing tobacco with or without a tip or mouthpiece not otherwise defined as a cigarette under Massachusetts General Law, Chapter 64C, Section 1, Paragraph 1.

Component part: Any element of a tobacco product, including, but not limited to, the tobacco, filter and paper, but not including any constituent.

Constituent: Any ingredient, substance, chemical or compound, other than tobacco, water or reconstituted tobacco sheet, that is added by the manufacturer to a tobacco product during the processing, manufacturing or packaging of the tobacco product. Such term shall include a smoke constituent.

[26] Druzik et al v. Board of Health of Haverhill, 324 Mass.129 (1949).

Coupon: Any card, paper, note, form, statement, ticket or other issue distributed for commercial or promotional purposes to be later surrendered by the bearer so as to receive an article, service or accommodation without charge or at a discount price.

Distinguishable: Perceivable by either the sense of smell or taste.

Educational Institution: Any public or private college, school, professional school, scientific or technical institution, university or other institution furnishing a program of higher education.

Employee: Any individual who performs services for an employer.

Employer: Any individual, partnership, association, corporation, trust or other organized group of individuals that uses the services of one (1) or more employees.

Flavored tobacco product: Any tobacco product or component part thereof that contains a constituent that has or produces a characterizing flavor. A public statement, claim or indicia made or disseminated by the manufacturer of a tobacco product, or by any person authorized or permitted by the manufacturer to make or disseminate public statements concerning such tobacco product, that such tobacco product has or produces a characterizing flavor shall constitute presumptive evidence that the tobacco product is a flavored tobacco product.

Health Care Institution: An individual, partnership, association, corporation or trust or any person or group of persons that provides health care services and employs health care providers licensed, or subject to licensing, by the Massachusetts Department of Public Health under M.G.L. c. 112 or a retail establishment that provides pharmaceutical goods and services and is subject to the provisions of 247 CMR 6.00. Health care institutions include, but are not limited to, hospitals, clinics, health centers, pharmacies, drug stores, doctor offices, optician/optometrist offices and dentist offices.

Liquid Nicotine Container: A bottle or other vessel which contains nicotine in liquid or gel form, whether or not combined with another substance or substances, for use in a tobacco product, as defined herein. The term does not include a container containing nicotine in a cartridge that is sold, marketed, or intended for use in a tobacco product, as defined herein, if the cartridge is prefilled and sealed by the manufacturer and not intended to be open by the consumer or retailer.

Listed or non-discounted price: The higher of the price listed for a tobacco product on its package or the price listed on any related shelving, posting, advertising or display at the place where the tobacco product is sold or offered for sale plus all applicable taxes if such taxes are not included in the state price, and before the application of any discounts or coupons.

Minimum Legal Sales Age (MLSA): The age an individual must be before that individual can be sold a tobacco product in the municipality.

Non-Residential Roll-Your-Own (RYO) Machine: A mechanical device made available for use (including to an individual who produces cigars, cigarettes, smokeless tobacco, pipe tobacco, or roll-your-own tobacco solely for the individual's own personal consumption or use) that is capable of making cigarettes, cigars or other tobacco products. RYO machines located in private homes used for solely personal consumption are not Non-Residential RYO machines.

Permit Holder: Any person engaged in the sale or distribution of tobacco products who applies for and receives a tobacco product sales permit or any person who is required to apply for a Tobacco Product Sales Permit pursuant to these regulations, or his or her business agent.

Person: Any individual, firm, partnership, association, corporation, company or organization of any kind, including but not limited to, an owner, operator, manager, proprietor or person in charge of any establishment, business or retail store.

Self-Service Display: Any display from which customers may select a tobacco product, as defined herein, without assistance from an employee or store personnel.

Schools: Public or private elementary or secondary schools.

Smoke Constituent: Any chemical or chemical compound in mainstream or sidestream tobacco smoke that either transfers from any component of the tobacco product to the smoke or that is formed by the combustion or heating of tobacco, additives or other component of the tobacco product.

Smoking Bar: An establishment that primarily is engaged in the retail sale of tobacco products for consumption by customers on the premises and is required by Mass. General Law Ch. 270, §22 to maintain a valid permit to operate a smoking bar issued by the Massachusetts Department of Revenue. "Smoking bar" shall include, but not be limited to, those establishments that are commonly known as "cigar bars" and "hookah bars".

Tobacco Product: Any product containing, made, or derived from tobacco or nicotine that is intended for human consumption, whether smoked, chewed, absorbed, dissolved, inhaled, snorted, sniffed, or ingested by any other means, including, but not limited to: cigarettes, cigars, little cigars, chewing tobacco, pipe tobacco, snuff; or electronic cigarettes, electronic cigars, electronic pipes, electronic hookah, liquid nicotine, "e-liquids" or other similar products, regardless of nicotine content, that rely on vaporization or aerosolization. "Tobacco product" includes any component or part of a tobacco product. "Tobacco product" also includes all nicotine delivery products. "Tobacco product" does not include any product that has been approved by the United States Food and Drug Administration either as a tobacco use cessation product or for other medical purposes and which is being marketed and sold or prescribed solely for the approved purpose.

Vending Machine: Any automated or mechanical self-service device, which upon insertion of money, tokens or any other form of payment, dispenses or makes cigarettes or any other tobacco products, as defined herein.

Workplace: Any enclosed area of a structure, indoor area, facility or a portion thereof at which one (1) or more employees perform services for their employer (including the personal residence of the employer during those hours when used as a place of employment); other enclosed spaces rented to or otherwise used by the public; and where the employer has the right or authority to exercise control over the space. It also include motor vehicles, employee lounges, restrooms, conference rooms, hallways, stairways and entrance ways, as well as exterior, unenclosed spaces at stairs, ramps, landings, patios, porches, decks, adjacent yards, loading docks and other areas within ~~twenty~~ fifty (~~20~~50) feet of the entrance doors or other areas where smoke would migrate into the enclosed area of a structure.

D. **Tobacco Sales to Persons Under the Minimum Legal Sales Age Prohibited:**

1. No person shall sell tobacco products or permit tobacco products, as defined herein, to be sold to a person under the minimum legal sales age; or not being the individual's parent or legal guardian, give tobacco products, as defined herein, to a person under the minimum legal sales age. The minimum legal sales age in Needham is 21 years.

2. Required Signage:

a. In conformance with and in addition to Massachusetts General Law, Chapter 270, Section 7, a copy of Massachusetts General Laws, Chapter 270, Section 6, shall be posted conspicuously by the owner or other person in charge thereof in the shop or other place used to sell tobacco products at retail. The notice shall be provided by the Massachusetts Department of Public Health and made available from the Needham Board of Health. The notice shall be at least 48 square inches and shall be posted conspicuously by the permit holder in the retail establishment or other place in such a manner so that it may be readily seen by a person standing at or approaching the cash register. The notice shall directly face the purchaser and shall not be obstructed from view or placed at a height of less than 4 feet or greater than 9 feet from the floor. The owner or other person in charge of a shop or other place used to sell tobacco products at retail shall conspicuously post any additional signs required by the Massachusetts Department of Public Health. The owner or other person in charge of a shop or other place used to sell hand rolled cigars must display a warning about cigar consumption in a sign at least 50 square inches pursuant to 940 CMR 22.06 (2) (e).

b. The owner or other person in charge of a shop or other place used to sell tobacco products, as defined herein, at retail shall conspicuously post signage provided by the Needham Board of Health that discloses current referral information about smoking cessation.

c. The owner or other person in charge of a shop or other place used to sell tobacco products that rely on vaporization or aerosolization, as defined herein as “tobacco products”, at retail shall conspicuously post a sign stating that “The sale of tobacco products, including e-cigarettes, to someone under the minimum legal sales age of 21 years is prohibited.” The notice shall be no smaller than 8.5 inches by 11 inches and shall be posted conspicuously in the retail establishment or other place in such a manner so that it may be readily seen by a person standing at or approaching the cash register. The notice shall directly face the purchaser and shall not be obstructed from view or placed at a height of less than four (4) feet or greater than nine (9) feet from the floor.

3. Identification: Each person selling or distributing tobacco products, as defined herein, shall verify the age of the purchaser by means of a valid government-issued photographic identification containing the bearer's date of birth that the purchaser is 21 years old or older. Verification is required for any person under the age of 27.

4. All retail sales of tobacco products, as defined herein, must be face-to-face between the seller and the buyer and occur at the permitted location.

5. No person or entity selling tobacco products shall allow anyone under twenty one (21) years of age to sell tobacco products.

E. **Tobacco Product Sales Permit:**

1. No person shall sell or otherwise distribute tobacco products, as defined herein, within the town of Needham without first obtaining a Tobacco Product Sales Permit issued annually by the Needham Board of Health. Only owners of establishments with a permanent, non-mobile location in Needham are eligible to apply for a permit and sell tobacco products, as defined herein, at the specified location in Needham**.**

2. As part of the Tobacco Product Sales Permit application process, the applicant will be provided with the Needham regulation. Each applicant is required to sign a statement declaring that the applicant has read said regulation and that the applicant is responsible for instructing any and all employees who will be responsible for tobacco product sales regarding federal, state and local laws regarding the sale of tobacco and this regulation.

3. As a condition for obtaining and/or renewing a Tobacco Sales Permit, the Needham Board of Health may require tobacco retailers and any employee involved in the act of sale of tobacco products to participate in training programs provided by or approved by the Board regarding compliance with the laws and regulations prohibiting the sale of tobacco products to minors and to individuals under the age of 21.

4. No Tobacco Sales Permit holder shall allow any employee to sell cigarettes or other tobacco products until such employee reads this regulation and state laws regarding the sale of tobacco products and signs a statement, a copy of which will be placed on file in the office of the employer, that the employee has read and understands the regulation and applicable state laws.

5. Each applicant who sells tobacco products is required to provide proof of a current Tobacco Retailer License issued by the Massachusetts Department of Revenue, when required by state law, before a Tobacco Product Sales Permit can be issued.

6. A separate permit, displayed conspicuously, is required for each retail establishment selling tobacco products, as defined herein. The fee for which shall be determined by the Needham Board of Health annually.

7. A Tobacco Product Sales Permit is non-transferable. A new owner of an establishment that wishes to sell tobacco products, as defined herein, must apply for a new permit Tobacco Product Sales Permit and one may only be issued at the Needham Board of Health's discretion. At the very least, no new permit will be issued unless and until all outstanding penalties incurred by the previous permit holder are satisfied in full.

8. Issuance of a Tobacco Product Sales Permit shall be conditioned on an applicant's consent to unannounced, periodic inspections of his/her retail establishment to ensure compliance with this regulation.

9. A Tobacco Product Sales Permit will not be renewed if the permit holder has failed to pay all fines issued and the time period to appeal the fines has expired and/or the permit holder has not satisfied any outstanding permit suspensions.

10. A Tobacco Product Sales Permit will not be renewed if the permit holder has sold a tobacco product to a person under the MLSA (§D.1) six times within the 36 month period of performance (which begins on the effective date of this regulation's amendment, July 1, 2017) and the time period to appeal has expired. The violator may request a hearing in accordance with subsection 4 of the Violations section.

11. Maximum Number of Tobacco Product Sales Permits.

a. At any given time, there shall be no more than ten (10) Tobacco Product Sales Permits issued in Needham **(**reduced by the number of permits not renewed pursuant to subsection (b) below). No permit

renewal will be denied based on the requirements of this subsection except any permit holder who has failed to renew his or her permit within thirty (30) days of expiration will be treated as a first-time permit applicant.

b. As of July 1, 2017, any permit not renewed because a retailer no longer sells tobacco products, as defined herein, or because a retailer closes the retail business, or because the ownership of the establishment with the Tobacco Product Sales Permit changes ownership, shall be returned to the Needham Board of Health and may, at the Board's discretion, be permanently retired by the Board of Health and the total allowable number of Tobacco Product Sales Permits under paragraph 11(a) shall be reduced by the number of the retired permits.

c. A Tobacco Product Sales Permit may, at the Board of Health's discretion, not be issued to any new applicant for a retail location within 500 feet of a public or private elementary or secondary school as measured by a straight line from the nearest point of the property line of the school to the nearest point of the property line of the site of the applicant's business premises. This provision does **not** apply to existing permit holders in good standing that are within 500 feet of a public or private elementary or secondary school.

d. A Tobacco Product Sales Permit may, at the Board of Health's discretion, not be issued to any new applicant for a retail location within 500 feet of an existing Tobacco Product Sales Permit holder as measured by a straight line from the nearest point of the proposed permit holder's property line to the nearest point of the property line of the site of the applicant's business premises. This provision does **not** apply to existing permit holders in good standing that currently located within an existing Tobacco Product Sales Permit holder.

e. Applicants who purchase an existing business that holds a valid Tobacco Product Sales Permit at the time of the sale of said business must apply within sixty (60) days of such sale for the permit held by the Seller if the Buyer intends to sell tobacco products, as defined herein, and permit issuance shall be subject to the conditions of this Section.

F. **Cigar Sales Regulated:**

1. No person shall sell or distribute or cause to be sold or distributed a single cigar.

2. No person shall sell or distribute or cause to be sold or distributed any original factory-wrapped package of two or more cigars, unless such package is priced for retail sale at $5.00 or more.

3. This Section shall not apply to:

a. The sale or distribution of any single cigar having a retail price of two dollars and fifty cents ($2.50) or more.
b. A person or entity engaged in the business of selling or distributing cigars for commercial purposes to another person or entity engaged in the business of selling or distributing cigars for commercial purposes with the intent to sell or distribute outside the boundaries of Needham**.**

4. The Needham Board of Health shall adjust, from time to time, the amounts specified in this Section to reflect changes in the applicable Consumer Price Index by amendment of this regulation.

G. **Sale of Flavored Tobacco Products Prohibited:**

No person shall sell or distribute or cause to be sold or distributed any flavored tobacco product, except in smoking bars and adult-only retail tobacco stores.

H. **Prohibition of the Sale of Blunt Wraps:**

No person or entity shall sell or distribute blunt wraps in Needham**.**

I. **Free Distribution and Coupon Redemption:** No person shall:

1. Distribute or cause to be distributed, any free samples of tobacco products, as defined herein;

2. Accept or redeem, offer to accept or redeem, or cause or hire any person to accept or redeem or offer to accept or redeem any coupon that provides any tobacco product, as defined herein, without charge or for less than the listed or non-discounted price; or

3. Sell a tobacco product, as defined herein, to consumers through any multi-pack discounts (e.g., "buy-two-get-one-free") or otherwise provide or distribute to consumers any tobacco product, as defined herein, without charge or for less than the listed or non-discounted price in exchange for the purchase of any other tobacco product.

4. Sections 2 and 3 shall not apply to products, such as cigarettes, for which there is a state law prohibiting them from being sold as loss leaders and for which a minimum retail price is required by state law.

J. **Out-of-Package Sales:**

1. The sale or distribution of tobacco products, as defined herein, in any form other than an original factory-wrapped package is prohibited, including the repackaging or dispensing of any tobacco product, as defined herein, for retail sale. No person may sell or cause to be sold or distribute or cause to be distributed any cigarette package that contains fewer than twenty (20) cigarettes, including single cigarettes.

2. A retailer of Liquid Nicotine Containers must comply with the provisions of 310 CMR 30.000, and must provide the Needham Board of Health with a written plan for disposal of said product, including disposal plans for any breakage, spillage or expiration of the product.

3. All retailers must comply with 940 CMR 21.05 which reads: "It shall be an unfair or deceptive act or practice for any person to sell or distribute nicotine in a liquid or gel substance in Massachusetts after March 15, 2016 unless the liquid or gel product is contained in a child-resistant package that, at a minimum, meets the standard for special packaging as set forth in 15 U.S. C.§§1471 through 1476 and 16 CFR §1700 et. Seq."

K. **Self-Service Displays:**

All self-service displays of tobacco products, as defined herein, are prohibited. All humidors including, but not limited to, walk-in humidors must be locked.

L. **Vending Machines:**

All vending machines containing tobacco products, as defined herein, are prohibited.

M. **Non-Residential Roll-Your-Own Machines:**

All Non-Residential Roll-Your-Own machines are prohibited.

N. **Prohibition of the Sale of Tobacco Products by Health Care Institutions:**

No health care institution located in Needham shall sell or cause to be sold tobacco products, as defined herein. No retail establishment that operates or has a health care institution within it, such as a pharmacy, optician/optometrist or drug store, shall sell or cause to be sold tobacco products, as defined herein.

O. **Prohibition of the Sale of Tobacco Products by Educational Institutions:**

No educational institution located in Needham shall sell or cause to be sold tobacco products, as defined herein. This includes all educational institutions as well as any retail establishments that operate on the property of an educational institution.

P. **Incorporation of Attorney General Regulation 940 CMR 21.00:**

The sale or distribution of tobacco products, as defined herein, must comply with those provisions found at 940 CMR 21.00 ("Sale and Distribution of Cigarettes, Smokeless Tobacco Products, and Electronic Smoking Devices in Massachusetts").

Q. **PROHIBITION ON SMOKING IN PUBLIC PLACES AND WORKPLACES:**No person shall smoke or use an e-cigarette nor shall any person having control of the premises upon which smoking is prohibited by this regulation or by M.G.L. c. 270, §22, or the business agent or designee of such person, permit a person to smoke or use an e-cigarette in any of the following places as defined herein: restaurants and all outdoor areas of restaurants, bars, taverns, and any other outdoor place where food and/or beverages, and/or non-alcoholic beverages are sold, served, or otherwise consumed or carried, health care facilities, municipal buildings, municipal vehicles, public places, public transportation, retail stores, town-owned parks and playgrounds, town-owned athletic fields, town-owned property, conservation land, nursing homes, hotels, motels, inns, bed and breakfast, lodging homes, any establishment that is required to possess a valid Tobacco Sales Permit from the Needham Board of Health (including, but not limited to, smoke shops, tobacconists, retail tobacco stores) and workplaces except as otherwise provided in § Q.2 of this regulation. It shall be the responsibility of the employer to provide a smoke-free environment for all employees working in an enclosed workplace as well as those workplaces listed. Additionally, no person shall smoke in any place in which a sign conforming to the requirements of Section Q.1 of this regulation is posted. No person shall remove a sign posted under the authority § Q.1 of this regulation.

1. Every person having control of premises upon which smoking is prohibited by and under the authority of this regulation shall conspicuously display upon the premises "No Smoking" signs provided by the Massachusetts

Department of Public Health and available from the Needham Board of Health or the international "No Smoking" symbol (consisting of a pictorial representation of a burning cigarette enclosed in a circle with a bar across it) and comparable in size to the sign provided by the Massachusetts Department of Public Health and available from the Needham Board of Health.

2. Notwithstanding any other provision of these regulations, smoking may be permitted in the following places and/or under the following circumstances consistent with all applicable state laws:

   a. Private residences except those portions used as a public place, food service establishment, child care, adult care, or health care office during the hours when operating as such.
   b. Hotel, motel, inn and bed and breakfast rooms rented to guests at smoke free (100%) at all times. A room so designated shall have signs posted indicating that no smoking is allowed**.**
   c. Private clubs if all employees are members. When a private club is open to the general public, that portion of said establishment open to the general public must be smokefree, separately enclosed and shall have self-closing doors. Premises occupied by a membership association, if the premises is owned, or under a written lease for a term of not less than 90 consecutive days, by an association during the time of the permitted activity if the premises are not located in a public building. Smoking may be permitted in a distinct part of the premises of a membership association, provided that this part (a) is physically separated from any area open to the public or occupied by a non-member who is not a guest. The separation shall be sufficient to prevent any migration of smoke into the public areas. Any doors separating the areas shall be self-closing; (b) is occupied solely by those persons specified in 105 CMR 661.100(b). The membership association shall adopt and effectively implement a policy that ensures only such persons are permitted to enter the part of the premises where smoking is permitted; and (c) there are no signs inviting or encouraging the public or non-members who are not guests to enter. No smoking shall be permitted in an enclosed indoor space of a membership association during the time the space is:

      1) open to the public. A membership association shall be regarded as open to the public when it has signs or advertising inviting or encouraging non-members to the premises or takes other action that may reasonably be regarded as inviting or allowing non-members to enter the premises.; or
      2) occupied by a non-member who is not an invited guest of a member or an employee of the association. A non-member shall be regarded as a guest if entering the premises (a) accompanied by a member, provided the member remains on the premises while the guest is present, and (b) signing a guest register that clearly specifies the name and address of the guest and the inviting member;
      3) rented from the association for a fee or other agreement that compensates the association for the use of such space; OR
      4) occupied by a contract employee, temporary employee or independent contractor.
      5) Smoking may be permitted in an enclosed indoor space of a membership association at all times, if the space is restricted by the association to admittance only of its members, the invited guest of a member, and the employees of the membership association. A person shall not be regarded as a member if entering the premises under terms of a membership that differ in duration, cost or privileges from the terms of a full membership in the association. A person who is a contract employee, temporary employee, or independent contractor shall be considered an employee of a membership association under this subsection. A person who is a member of an affiliated chapter or

branch of a membership association that is fraternal in nature operating under the lodge system, and is visiting the affiliated association, shall be an invited guest for the purpose of this association.

Nothing shall prohibit an establishment from being completely smokefree.

R. **Smoking Bars:**

Smoking bars are prohibited in the Town of Needham.

S. **Violations:**

1. It shall be the responsibility of the establishment, permit holder and/or his or her business agent to ensure compliance with all sections of this regulation. The violator shall receive:

a. In the case of a first violation, a fine of three hundred dollars ($300.00) and the Tobacco Product Sales Permit shall be suspended for seven (7) consecutive business days.
b. In the case of a second violation within 36 months of the date of the first violation, a fine of three hundred dollars ($300.00) and the Tobacco Product Sales Permit shall be suspended for fourteen (14) consecutive business days.
c. In the case of a third violation within 36 months of the date of the first violation, a fine of three hundred dollars ($300.00) and the Tobacco Product Sales Permit shall be suspended for thirty (30) consecutive business days.
d. In the case of a fourth violation within 36 months of the date of the first violation, a fine of three hundred dollars ($300.00) and the Tobacco Product Sales Permit shall be suspended for ninety (90) consecutive business days.
e. In the case of a fifth violation or repeated, egregious violations of this regulation within a 36 month period, the Board of Health shall hold a hearing in accordance with subsection 4 of this section and shall permanently revoke a Tobacco Product Sales Permit.

2. Refusal to cooperate with inspections pursuant to this regulation shall result in the suspension of the Tobacco Product Sales Permit for thirty (30) consecutive business days.

3. In addition to the monetary fines set above, any permit holder who engages in the sale or distribution of tobacco products while his or her permit is suspended shall be subject to the suspension of all Board of Health issued permits for thirty (30) consecutive business days.

4. The Needham Board of Health shall provide notice of the intent to suspend or revoke a Tobacco Product Sales Permit, which notice shall contain the reasons therefor and establish a time and date for a hearing which date shall be no earlier than seven (7) days after the date of said notice. The permit holder or its business agent shall have an opportunity to be heard at such hearing and shall be notified of the Board of Health's decision and the reasons therefor in writing. After a hearing, the Needham Board of Health shall suspend or revoke the Tobacco Product Sales Permit if the Board of Health finds that a violation of this regulation occurred. For purposes of such suspensions or revocations, the Board shall make the determination notwithstanding any separate criminal or non-criminal proceedings brought in court hereunder or under the Massachusetts General Laws for the same offense. All tobacco products, as defined herein, shall be removed from the retail

establishment upon suspension or revocation of the Tobacco Product Sales Permit. Failure to remove all tobacco products, as defined herein, shall constitute a separate violation of this regulation.

T. **Non-Criminal Disposition:**

Whoever violates any provision of this regulation may be penalized by the non-criminal method of disposition as provided in Massachusetts General Laws, Chapter 40, § 21D or by filing a criminal complaint at the appropriate venue.

U. **Separate Violations:** Each day any violation exists shall be deemed to be a separate offense.

V. **Enforcement:**

Enforcement of this regulation shall be by the Needham Board of Health, its Director of Health & Human Services, and its designated agents.

Any resident who desires to register a complaint pursuant to the regulation may do so by contacting the Needham Board of Health or its designated agent(s) and the Board shall investigate.

W. **Severability:**

If any provision of this regulation is declared invalid or unenforceable, the other provisions shall not be affected thereby but shall continue in full force and effect.

X. **Effective Date:**

A public meeting about this regulation occurred in ~~July~~ September and October 2018. A public hearing occurred on ~~September 14~~November 16, 2018. This regulation was approved by a [unanimous] vote of the Needham Board of Health on ~~September 14~~November 16, 2018, and shall take effect on ~~November 1~~January 15, 201~~8~~9. A notice and summary of the regulation was posted by the Needham Town Clerk, was posted on the Needham Public Health Division's website, and was published in a newspaper in circulation in the Town of Needham. Copies of this regulation have also been filed with the Needham Town Clerk and the Massachusetts Department of Environmental Protection.

The original Needham Board of Health smoking and tobacco regulation was enacted in September 1991. It has been amended extensively over the years, most notably in 2005 with the enactment of the Tobacco 21 policy, which was phased-in over a three year period. This regulation was amended again in 2009 with the implementation of a prohibition on the sale of tobacco products in pharmacies. A ban on flavored tobacco was incorporated in 2015.

Adolescent Exposure to Toxic Volatile Organic Chemicals From E-Cigarettes

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abstract

BACKGROUND: There is an urgent need to understand the safety of e-cigarettes with adolescents. We sought to identify the presence of chemical toxicants associated with e-cigarette use among adolescents.

METHODS: Adolescent e-cigarette users (≥1 use within the past 30 days, ≥10 lifetime e-cigarette use episodes) were divided into e-cigarette–only users (no cigarettes in the past 30 days, urine 4-[methylnitrosamino]-1-[3-pyridyl]-1-butanol [NNAL] level <1 pg/mL of creatinine; n = 67), dual users (use of cigarettes in the past 30 days in addition to e-cigarettes, NNAL level >30 pg/mL; n = 16), and never-using controls (N = 20). Saliva was collected within 24 hours of the last e-cigarette use for analysis of cotinine and urine for analysis of NNAL and levels of 8 volatile organic chemical compounds. Bivariate analyses compared e-cigarette–only users with dual users, and regression analyses compared e-cigarette–only users with dual users and controls on levels of toxicants.

RESULTS: The participants were 16.4 years old on average. Urine excretion of metabolites of benzene, ethylene oxide, acrylonitrile, acrolein, and acrylamide was significantly higher in dual users versus e-cigarette–only users (all $P < .05$). Excretion of metabolites of acrylonitrile, acrolein, propylene oxide, acrylamide, and crotonaldehyde were significantly higher in e-cigarette–only users compared with controls (all $P < .05$).

CONCLUSIONS: Although e-cigarette vapor may be less hazardous than tobacco smoke, our findings can be used to challenge the idea that e-cigarette vapor is safe, because many of the volatile organic compounds we identified are carcinogenic. Messaging to teenagers should include warnings about the potential risk from toxic exposure to carcinogenic compounds generated by these products.

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Drs Rubinstein, Delucchi, Ramo, and Benowitz made substantial contributions to the conception and design of the study and to the analysis and interpretation of data, participated in and made substantial contributions to the drafting of the manuscript for important intellectual content, and are in agreement to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; and all authors approved the final manuscript as submitted.

DOI: https://doi.org/10.1542/peds.2017-3557

Accepted for publication Jan 23, 2018

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PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275).

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WHAT'S KNOWN ON THIS SUBJECT: The presence of harmful ingredients in electronic cigarette vapor has been established.

WHAT THIS STUDY ADDS: We have demonstrated that at least 5 potentially harmful toxicants are found in the body of human adolescents who use electronic cigarettes.

To cite: Rubinstein ML, Delucchi K, Benowitz NL, et al. Adolescent Exposure to Toxic Volatile Organic Chemicals From E-Cigarettes. *Pediatrics.* 2018;141(4):e20173557

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Electronic cigarettes (e-cigarettes) are marketed to promote smoking cessation or reduced cigarette smoking in adults.[1] However, social influence and marketing strategies for these products have clearly had an effect on children as well, because more teenagers now use e-cigarettes than traditional cigarettes.[2] In 2016, e-cigarette use in the past 30 days among 10th-graders was more than twice that of cigarette use (11.0% vs 4.9%).[3] Reasons for the dramatic increase in adolescent e-cigarette use include peer influence, enticing flavors,[4] and extensive marketing presenting e-cigarettes as safer.[5,6] Common messages found on product Web sites are that e-cigarettes do not produce the same cancer-causing agents as traditional cigarettes.[1]

Despite advertising claims, there is uncertainty about the safety of e-cigarettes. By using aerosolized nicotine rather than combusting tobacco, e-cigarettes do produce fewer toxins than smoking cigarettes.[7] However, e-cigarettes contain additives and solvents, including propylene glycol and/or glycerol, which can form carcinogenic compounds when heated.[8–11] These and other toxic chemicals[12] may be inhaled through the vapor produced. Although there is some controversy on how use patterns may affect exposure, some data from adults reveal that these toxicants can be detected in the urine of e-cigarette users.[13,14] Importantly, these studies did not exclude participants with a possible exposure to secondhand smoke.

To our knowledge, there are no data on toxicant exposure in adolescent e-cigarette users. However, there is great concern because exposure to toxicants during adolescence may result in greater harm than exposure in adulthood, given vulnerability to the acute and chronic effects of toxicants in general and from their cumulative exposure if started early.[15]

Given the rapid uptake of e-cigarettes among teenagers, there is an urgent need to understand the safety of these products in adolescents, including how use contributes to toxicant exposure. In this study, we sought to assess in adolescents the presence of certain carcinogenic toxicants linked to e-cigarette use and examine how specific behavioral patterns of use may influence exposure to toxicants.

METHODS

Participants and Procedures

As part of an ongoing longitudinal study of the effects of e-cigarettes on adolescents, adolescent (aged 13–18 years) e-cigarette users (used an e-cigarette product on ≥1 day in the past 30 days and had at least 10 lifetime use episodes) were recruited from the San Francisco Bay area by using fliers and online advertising. The research design and procedures were reviewed and approved by the University of California Institutional Review Board.

To capture nicotine exposure and investigate the presence of toxicants, participants were instructed to schedule their baseline appointments in temporal proximity (ie, past 24 hours) to use of their e-cigarettes. Adolescents were never pressured or instructed to use e-cigarettes, and in the cases in which no use occurred, appointments were rescheduled. After signing consents, participants completed a baseline survey including questions about demographics and e-cigarette use behaviors. Participants then provided saliva samples for cotinine measurement and urine for the measurement of the tobacco-specific nitrosamine 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol (NNAL) and levels of metabolites of 8 volatile organic compounds (VOCs). Participants received $30.

Specimens were also collected from 20 age-matched control adolescents attending pediatric clinics at a Bay area public hospital with undetectable cotinine and NNAL, confirming no e-cigarette or nicotine use. These adolescents were part of another study on secondhand smoke exposure for which urine was collected and analyzed for NNAL and cotinine.

Measures

Biological

Saliva and urine samples were analyzed at the Clinical Pharmacology Laboratory at the University of California, San Francisco. Salivary specimens were analyzed for cotinine, the main proximate metabolite of nicotine, by using liquid chromatography–tandem mass spectrometry.[16,17] Urine was analyzed for NNAL, a metabolite of 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanone, a tobacco-specific nitrosamine that is a potent carcinogen,[13,18] by liquid chromatography–tandem mass spectrometry.[18] This was done as an adjunct to self-reported tobacco smoking and to rule out significant secondhand tobacco smoke exposure (or exposure from marijuana blunts), because NNAL is detectable in urine for 6 to 12 weeks after exposure.[19] Urine was analyzed for metabolites of a panel of 8 VOCs that are toxic environmental or tobacco smoke constituents, including benzene (phenylmercapturic acid [PMA]), 1, 3-butadiene (4-hydroxy-2-buten-1-yl-mercapturic acid), ethylene oxide (2-hydroxyethylmercapturic acid [HEMA]), acrylonitrile (2-cyanoethylmercapturic acid [CNEMA]), acrolein (3-hydroxypropylmercapturic acid [3-HPMA]), propylene oxide (2-hydroxypropylmercapturic acid [2-HPMA]), acrylamide (2-carbamoylethylmercapturic acid [AAMA]), and crotonaldehyde (3-hydroxy-1-methyl-

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propylmercapturic acid [HMPMA]).[20] Both NNAL and VOC concentrations were normalized for creatinine.[21]

Demographic, E-Cigarette, and Smoking Characteristics

Demographic variables included race and/or ethnicity, sex, and age. Individuals who identified as Hispanic were classified as such, regardless of race. A measure of e-cigarette use was designed for this study that included the time of last use (used to calculate hours since last use), frequency of use (days used in the past month), quantity of use (average sessions per day on using days, calculated by asking how many times they used their devices on each weekday and weekend day and then dividing by 7), usual number of puffs per session in 4 categories (1–4, 5–10, 10–15, or >15), length of each session in 4 categories (1–2, 3–5, 6–10, or >10 minutes), main type of e-cigarette used in 4 categories (vape pen, modified, Juul, other), whether e-cigarettes contained nicotine (always, sometimes, unsure, or never), and the flavors consumed in the past month (fruit, candy, menthol, or tobacco; yes or no). Tobacco use was assessed by asking if participants smoked a cigarette in the past 30 days (yes or no).

Data Analyses

Three categories were developed on the basis of the combination of reported e-cigarette and cigarette use and urine NNAL levels. E-cigarette–only users had used no traditional combustion cigarettes in the past 30 days and had levels of urine NNAL <1 pg/mL of creatinine. We used 1 pg per milliliter of creatinine to exclude smokers on the basis of our data to distinguish adolescents who were smokers from those who were nonsmokers in San Francisco.[22] Values between 0 and 1 pg/mg indicate no recent active smoking and either past smoking or light secondhand smoke exposure, neither of which would be expected to substantially increase VOC exposure. Dual users reported use of traditional cigarettes in the past 30 days in addition to e-cigarettes and had to have NNAL levels >30 pg/mL of creatinine. We chose a cutoff of 30 pg/mL of creatinine to ensure primary exposure to combusted tobacco. To ensure no exposure to combusted tobacco or nicotine from other sources (including e-cigarettes), controls had to have levels of NNAL and cotinine below the limit of quantitation (ie, 0.25 and 1 ng/mL respectively). We excluded from analyses participants who did not use an e-cigarette in the previous 24 hours because most VOCs in smokers, including those tested here, decline to baseline levels within 24 hours.[23] Finally, for the purposes of creating well-differentiated comparison groups, we also set an a priori exclusion from analyses for those participants who had intermediate levels of NNAL (ie, 1–29 pg/mL of creatinine), because the true source of exposure would be unclear. Conservative criteria for group definitions meant that the e-cigarette–only group was clearly differentiated from the dual user group, and any VOCs found in the e-cigarette–only group could be clearly attributed to e-cigarette use.

Descriptive statistics were used to characterize sociodemographic and e-cigarette use, *t* tests were used for continuous variables, and Pearson's χ^2 tests were used for categorical variables. Because of skew, the nonparametric Mann–Whitney *U* test was used to compare the distributions on hours since last use between e-cigarette–only and dual users.

Medians were reported for cotinine, NNAL, and all 8 VOCs because of non-normal distribution. Regression models including planned covariates (sex, race and/or ethnicity) compared e-cigarette–only users (reference group) with dual users and controls on log-transformed levels of VOCs (8 models). Among e-cigarette–only users, Pearson's *r* was used to calculate associations between levels of VOCs and e-cigarette use characteristics. For any models revealing significant differences in levels of VOCs between e-cigarette–only users and controls, analysis of variance was used to examine VOCs by type of product used, and *t* tests were used to compare VOCs by the presence or absence of flavors used in the past month.

Although we tried to eliminate exposure to blunts (tobacco mixed with marijuana) using NNAL, we could not exclude the potential contribution of VOC exposure from marijuana smoking on the day of the study.[24] Consequently, we estimated and tested regression models of log-transformed VOC values that were significant in the first set of analyses, including planned covariates (sex, race and/or ethnicity), with the additional covariate of self-reported frequency of marijuana use.

RESULTS

Three hundred eighty-six adolescents were screened, 229 were found to be eligible, and 180 agreed to participate. After verbally reporting use within 24 hours, 29 participants admitted on their surveys to not using an e-cigarette product in the previous 24 hours and thus were excluded from analyses. An additional 48 adolescents had levels of NNAL that might be consistent with substantial secondhand exposure or occasional cigarette smoking (ie, 1–29 pg per milligram of creatinine) and, as per our a priori criteria described above, were excluded from analyses. The final sample consisted of 67 e-cigarette–only users, 16 dual users, and 20 controls.

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E-Cigarette Use Behaviors

E-cigarette–only users reported using their e-cigarettes a mean of 12.8 days (SD = 8.9) a month compared with 25.5 days (SD = 6.6) for dual users ($P < .001$) (Table 1). There was no difference in time since the last use of e-cigarettes between e-cigarette–only (mean: 2:02 hours) and dual users (mean: 1:58 hours; $P > .91$). Among e-cigarette–only users, the level of salivary cotinine was significantly associated with both the number of days using an e-cigarette in the past 30 days ($r = 0.34$; $P < .01$) and the mean number of use sessions a day ($r = 0.75$; $P < .001$).

E-cigarette–only participants who reported using nicotine containing products "all" or "some" of the time had significantly higher levels of saliva cotinine compared with those who "never" used or were "unsure" if there was nicotine in their e-cigarettes (31 ng/mL [SD = 130.8] versus 0.08 ng/mL [SD = 0.38]; $P < .001$). E-cigarette–only participants who used nicotine in their e-cigarettes also reported using their e-cigarettes more frequently, with an average use of 15.1 (SD = 9.2) days per month compared with 7.6 (SD = 5.6) days ($P < .001$) and an average of 2.5 (SD = 4.0) sessions per day on days they used versus 0.65 (SD = 0.61) sessions ($P < .01$).

TABLE 1 E-Cigarette Use Characteristics

Characteristic	E-Cigarette–Only Users,[a] $n = 67$, Mean (SD) or No. (%)	Dual Users,[b] $n = 16$, Mean (SD) or No. (%)	Controls, $n = 20$, Mean (SD) or No. (%)	P[c]
Age	16.3 (1.2)	17.1 (0.96)	16.0 (1.8)	.06
Sex (male)	49 (73%)	12 (80%)	7 (35%)	<.01
Race and/or ethnicity				<.01
Non-Hispanic white	36 (54%)	9 (67%)	0	
Asian American or Pacific Islander	12 (19%)	2 (12%)	2 (10%)	
Multiracial	10 (15%)	3 (19%)	0	
Hispanic	7 (10%)	2 (12%)	18 (90%)	
Hours since last e-cigarette[d]	1:58 (6:29)	2:02 (7:17)	N/A	>.91
Days used in past 30 d	12.8 (8.9)	25.5 (6.6)	N/A	<.001
Sessions per day	2.0 (3.6)	8.4 (11.6)	N/A	.05
Usual puffs per session			N/A	.49
1–4	14 (21%)	1 (7%)		
5–10	21 (31%)	4 (27%)		
10–15	11 (16%)	4 (27%)		
>15	21 (31%)	6 (40%)		
Usual length of session			N/A	.97
1–2 min	8 (12%)	2 (13%)		
3–5 min	16 (24%)	4 (27%)		
6–10 min	16 (24%)	4 (27%)		
>10 min	27 (40%)	5 (33%)		
Usual type of device			N/A	.82
Vape pen	24 (36%)	6 (40%)		
Modified	17 (25%)	4 (27%)		
Juul	18 (27%)	4 (27%)		
Other or unsure	8 (12%)	1 (7%)		
E-cigarettes contain nicotine			N/A	.06
Always	21 (31%)	9 (60%)		
Sometimes	26 (39%)	6 (40%)		
Unsure	10 (15%)	0 (0%)		
Never	10 (15%)	0 (0%)		
Usual flavor of e-cigarette[e]			N/A	
Fruit	37 (55%)	10 (67%)		.42
Candy	11 (16%)	2 (13%)		.77
Menthol	12 (18%)	2 (13%)		.67
Tobacco	5 (8%)	2 (13%)		.46

N/A, not applicable.

[a] Used an e-cigarette product in the past 24 h and had NNAL levels <1 ppm of creatinine.

[b] Used an e-cigarette product in the past 24 h, smoked a cigarette in the past 30 d, and had NNAL levels ≥30 ppm of creatinine.

[c] P values are the result of comparing 3 groups on age (analysis of variance), sex, and ethnicity (χ^2); all e-cigarette characteristics are the result of comparing e-cigarette–only use to dual-use groups (t tests for continuous variables and χ^2 analyses for categorical variables).

[d] The median was reported because of non-normal distribution.

[e] Participants could select >1.

Presence and Comparison of VOCs

Urine excretion of metabolites of benzene (PMA), ethylene oxide (HEMA), acrylonitrile (CNEMA), acrolein (3-HPMA), and acrylamide (AAMA) was significantly higher in dual users versus e-cigarette–only users and controls (all $P <$ .05; see Table 2; Fig 1). Excretion of metabolites of 5 VOCs was significantly higher in e-cigarette–only users compared with controls (all $P < .05$): acrylonitrile (341% higher than in controls but 327% lower than in dual users), acrolein (20% higher than in controls but 11% lower than in dual users), propylene oxide (51% higher than in controls but 8% lower than in dual users; 2-HPMA), acrylamide (30% higher than in controls but 23% lower than in dual users), and crotonaldehyde (20% higher than in controls but 7% lower than in dual users; HMPMA).

We reran the 5 regression models used to predict the 5 log-transformed VOC values that were significant in the first set of analyses, including predictors of planned covariates (sex, race and/or ethnicity) and contrasts between e-cigarette–only users and dual users, with the additional covariate of self-reported frequency of marijuana use. In all models, group

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TABLE 2 Biomarkers of Nicotine, Tobacco-Specific Nitrosamine, and Volatile Organic Toxicants in Exclusive E-Cigarette–Only Users Versus Dual Users and Controls

Variable	E-Cigarette–Only Users,[a] $n = 67$			Dual Users,[b] $n = 16$			Controls,[c] $n = 20$		
	Median[d]	IQR	Range	Median[e]	IQR	Range	Median[e]	IQR	Range
Saliva cotinine (ng/mL)	0	3.8	0–864.6	99.4**	139.0	36.2–302.8	0*	0	0
Urine NNAL (pg/mL of creatinine)	0.3	0.7	0–0.9	68.1**	68.7	32.7–299.3	0**	0	0
PMA (ng/mg of creatinine; benzene)	0	0.1	0–2.0	0.2**	0.7	0–2.4	0	0	0–0.1
MHBMA (ng/mg of creatinine; 1,3-butadiene)	0	0	0–2.2	0	0.1	0–0.2	0*	0.5	0–1.1
HEMA (ng/mg of creatinine; ethylene oxide)	0.5	1.1	0–7.6	1.0*	1.4	0–8.2	1.3	2.3	0–4.0
CNEMA (ng/mg of creatinine; acrylonitrile)	1.3	3.2	0–108.4	59.4**	81.3	3.7–142.6	0**	1.1	0–1.6
3-HPMA (ng/mg of creatinine; acrolein)	254.3	191.4	0–2311.6	439.7*	224.1	153.6–814.4	192.8*	261.6	0–1416.4
2-HPMA (ng/mg of creatinine; propylene oxide)	28.8	25	0–1382.6	40.2	27.9	10.2–310.9	15.2**	14.4	0–34.5
AAMA (ng/mg of creatinine; acrylamide)	67.3	69	0–581.2	235.6**	239.8	41.4–574.7	34.5**	41.6	0–182.0
HMPMA (ng/mg of creatinine; crotonaldehyde)	148.7	99	0–793.4	185.4	156.6	110.0–437.9	100.4*	129.9	0–522.1

All comparisons were made with e-cigarette–only users as a comparison group. IQR, interquartile range; MHBMA, 4-hydroxy-2-buten-1-yl-mercapturic acid.

[a] Used an e-cigarette product in the past 24 h and had NNAL levels <1 pg/mL of creatinine.

[b] Used an e-cigarette product in the past 24 h, smoked a cigarette in the past 30 d, and had NNAL levels ≥30 pg/mL of creatinine.

[c] No use of tobacco or e-cigarette in the past 30 d, with NNAL levels <1 pg/mL of creatinine and cotinine levels <1 ng/mL.

[d] The median (IQR) was reported for cotinine, NNAL (pg/mL of creatinine), and VOCs (ng/mg of creatinine) because of non-normal distribution.

[e] Tests were based on regression models of log-transformed values, including planned covariates (sex and race and/or ethnicity) with contrasts for e-cigarette–only users versus controls and for e-cigarette–only users versus dual users.

* $P < .05$; ** $P < .001$.

membership remained a statically significant predictor of VOC value (dual users > e-cigarette–only users), accounting for variance independent of marijuana use frequency.

Associations Between VOCs and E-Cigarette Use

Among e-cigarette–only users, levels of the 5 VOCs (ie, CNEMA, 3-HPMA, 2-HPMA, AAMA, HMPMA) that were significantly greater than the levels found in controls were not associated with time since last e-cigarette use (*P* values ranged from .53 to .92). Compared with those who never used nicotine in their e-cigarettes or were unsure, participants who reported using nicotine in their e-cigarettes all or some of the time had significantly higher median levels of urinary CNEMA (1.50 vs 0.88 ng/mL creatinine; $P = .05$) and AAMA (71.5 vs 60.4 ng/mL creatinine, $P = .05$). The average number of sessions of e-cigarette use per day was associated with increased levels of CNEMA ($r = 0.36$, $P = .003$). Days of use in the past month was not associated with any increases in urinary VOC levels (*P* values raged from .21 to .72) among e-cigarette–only users.

There were no differences in levels of the 5 significant VOCs that were based on that type of product used (F test scores ranged from 0.51 to 2.3; *P* values ranged from .09 [for 2-HPMA] to .67). Participants who reported using fruit flavors in the past month had higher CNEMA levels than those who did not (yes: mean = 10.4 ng/mL creatinine [SD = 21.7]; no: mean 2.1 ng/mL creatinine [SD = 3.4]; $P = .03$). There were no differences in VOC levels among those who favored candy (*P* values ranged from .33 to .87), tobacco (*P* values ranged from .42 to .87), or menthol flavors (*P* values ranged from .09 [for 2-HPMA] to .95) compared with those who did not.

DISCUSSION

To the best of our knowledge, this is the first study to report on the presence of VOC toxicants in adolescent e-cigarette users. Overall results reveal significantly greater toxicant exposure in adolescent e-cigarette users compared with their nonusing peers. Adolescent e-cigarette–only users had levels of 5 VOC toxicants detected in their urine in quantities up to 3 times greater than in matched controls, including metabolites of acrylonitrile, acrolein, propylene oxide, acrylamide, and crotonaldehyde. Levels of toxicant exposure in dual users were up to 3 times higher than in those who used only e-cigarettes. Post hoc analyses revealed that, among dual users, levels of VOCs were not associated with NNAL (*P* values ranged from .17 to .81), suggesting that the higher VOCs were not only due to exposure to traditional cigarettes.

The presence of harmful ingredients in e-cigarette vapor has been established[25]; we can now say that these chemicals are found in the body of human adolescents who use these products. A risk analysis of lifelong exposure to even low-level VOCs, derived using data from secondhand tobacco smoke exposure, indicated an increased cancer risk, which could be applicable to exposure in the current study.[26] Of course, this assumes that the exposures will be ongoing, which has not yet been established. It is worth noting that although e-cigarette–only users had significantly higher exposure to 5 VOCs, controls also had detectable levels of these chemicals. In fact, human exposure to VOCs from environmental sources is ubiquitous.[27] It is also worth

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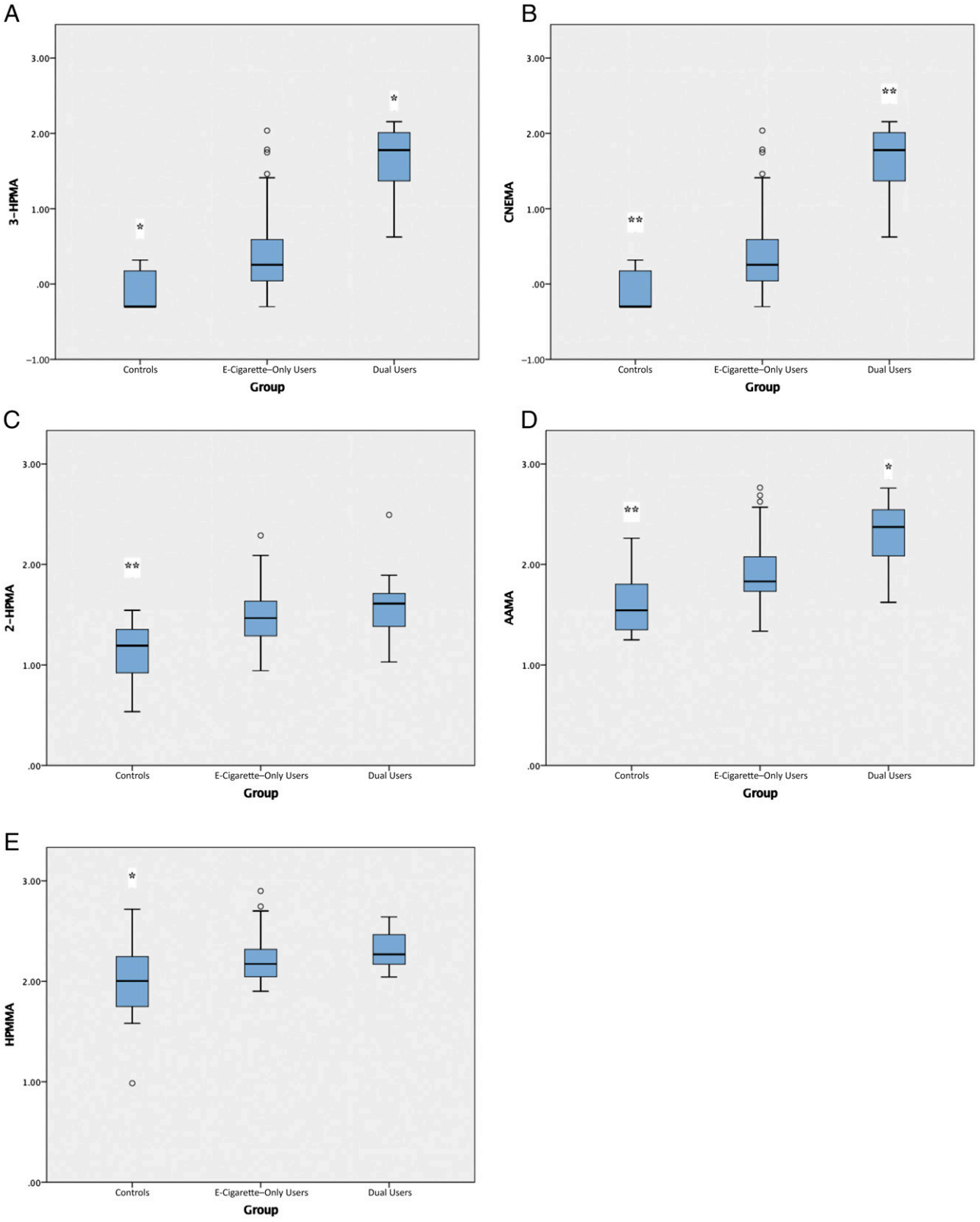

FIGURE 1

Significant VOC exposure in e-cigarette–only users versus controls and e-cigarette–only users versus dual users. A, Acrolein. B, Acrylonitrile. C, Propylene oxide. D, Acrylamide. E, Crotonaldehyde. Tests were based on regression models of shifted log-transformed values, including planned covariates (sex, race and/or ethnicity), with contrasts for e-cigarette–only users versus controls and e-cigarette–only users versus dual users. All comparisons are made with e-cigarette–only users as the comparison group. * $P < .05$; ** $P < .001$.

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noting that levels of VOCs detected in e-cigarette–only users were on average lower than has been reported among adults.[13,14,28] For example, using a similar methodology, Pulvers et al[14] reported the following median levels among exclusive e-cigarette users: CNEMA of 20.3 ng/mg of creatinine (versus 1.3 ng/mg in our sample), 3-HPMA of 370.3 ng/mg (versus 254.3 ng/mg), 2-HPMA of 38.0 ng/mg (versus 28.8 ng/mg), AAMA of 96.5 ng/mg (versus 67.3 ng/mg), and HMPMA of 251.6 ng/mg (versus 148.7 ng/mg). However, participants reported more frequent use of e-cigarettes in that study (ie, 24.7 days in the past 30 days and an average of 11.8 times per day on use days), and exclusive use of e-cigarettes was based on self-report only, because this was a switching study in which NNAL levels would not have had time to decline to nonexposed levels. Thus, the increase in VOCs among adults might be reflective of greater exposure to e-cigarettes and/or combustion products. Moreover, unlike our study, none of the authors of these studies employed a control group to account for baseline levels of environmental VOCs.

Nicotine

Not surprisingly, e-cigarette–only participants who reported using nicotine-containing products all or some of the time had significantly higher levels of cotinine compared with those who never used or were unsure if there was nicotine in their e-cigarettes. To the best of our knowledge, this is the first study to report cotinine levels in adolescent e-cigarette–only users. Among e-cigarette–only users, only the VOCs CNEMA and AAMA were higher in users of nicotine containing e-cigarettes. Levels of the 3 other significant and likely toxic VOCs were just as high in users of nonnicotine products as in those using nicotine. This is particularly important because many teenagers initiate e-cigarette use with nicotine-free products,[4] in part because they feel that they are safer.[29]

Type of Product

There were no significant differences found in levels of toxicants by type of product used. Despite a small number of subjects using each type of product, there was great variability among the 3 main types of e-cigarette products used by our participants. Given the results of studies of emissions among adult users of e-cigarettes, which revealed significant differences by brand and type of product,[25,30–32] the small numbers of users and variable use patterns among products may have limited our ability to detect small exposure-related differences among products.

Flavorings

There are researchers who suggests that certain flavorings may generate higher levels of toxic chemicals than others.[32–35] Among our e-cigarette–only participants, the use of fruit-flavored products produced significantly higher levels of the metabolites of acrylonitrile. This is of particular interest to adolescent e-cigarette use, because 1 of the main reasons teenagers report using e-cigarettes is the appealing flavors.[4] Moreover, for various reasons, including the stigma associated with tobacco, some may also feel that the fruit-flavored products are safer than tobacco-flavored products. In fact, fruit flavors were the most popular choice among our e-cigarette users with roughly 55% of e-cigarette–only users and 67% of dual users reporting using fruit flavors most often.

In addition to being the first to report toxicant levels in the urine of adolescent e-cigarette users, we used strict criteria based on objective biomarkers to avoid secondary sources of VOCs by excluding participants with any evidence of exposure to combustion products from tobacco from our e-cigarette–only group. Another strength of this study is the use of age-matched controls to account for the underlying rate of environmental exposures to 8 toxicants. We did not specifically test for marijuana exposure, a task which is fraught with difficulty, given the limitations of the testing itself, which are due to the long half-life of δ-9-tetrahydrocannabinol.[36,37] Despite this, our analyses revealed that it is unlikely that the variance in VOCs explained by our e-cigarette use group was accounted for by marijuana use instead of e-cigarette use.

Other limitations of this study include the fact that a wide range of e-cigarette products were used among participants, and thus, it may be difficult to pinpoint variability in toxicant exposure on the basis of the self-reported product used. However, this strengthens the external validity of the study because it gives a more real-world view of the toxicants found from the e-cigarette products commonly used by adolescents. We also only tested 8 likely toxic VOCs, but there may be other significant toxicants, including formaldehyde, which can be produced by e-cigarettes and which could pose a threat to adolescent users of these products; however, formaldehyde exposure is difficult to assess in vivo.[25] Although the focus of this study was on e-cigarette–only users, we also had a relatively small number of confirmed (ie, using NNAL) dual users. Lastly, controls were on average more likely to be female and Hispanic compared with e-cigarette–only and dual users. However, we do not feel that this played a role in our VOC findings because the analyses accounted for both sex and race and/or ethnicity. There may be other factors that could have influenced VOC levels, but given the sample size, we limited the number of covariates we included in any analysis. Larger prospective studies are needed to confirm the findings reported here

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to test for recent marijuana use and examine changes over time, perhaps with more complex matching.

CONCLUSIONS

Although e-cigarette vapor may be less dangerous than combustible cigarettes, with lower overall exposure to VOC toxicants, with our findings, we challenge the idea that e-cigarette vapor is safe. Many of the VOCs we identified among e-cigarette users are carcinogenic, including propylene oxide, acrylamide, acrylonitrile, and crotonaldehyde.[13] With few exceptions, these toxicants were present whether the product contained nicotine or flavorings. Consequently, as with traditional cigarettes, messaging to teenagers must include warnings about the potential risk from toxic exposure to carcinogenic compounds generated by these products.

ACKNOWLEDGMENTS

We thank Mr Richard Ceballos III, Mrs Judy Gonzalez-Vargas, Dr Karma McKelvey, Mr Michael Berry, Mr Mark Thomas, and Mr Jerome Andres for their assistance with data collection and participant recruitment. We are also grateful to Lisa Yu and Peyton Jacob III for assistance with biomarker assays. We thank Trisha Mao, Ethan Yip, Lawrence Chan, and Kristina Bello for performing analytical chemistry. We thank Dr Judith Prochaska for feedback on an earlier draft of the manuscript.

ABBREVIATIONS

AAMA: 2-carbamoylethylmercapturic acid
CNEMA: 2-cyanoethylmercapturic acid
e-cigarette: electronic cigarette
HEMA: 2-hydroxyethylmercapturic acid
HMPMA: 3-hydroxy-1-methyl-propylmercapturic acid
NNAL: 4-(methylnitrosamino)-1-(3-pyridyl)-1-butanol
PMA: phenylmercapturic acid
VOC: volatile organic compound
2-HPMA: 2-hydroxypropylmercapturic acid
3-HPMA: 3-hydroxypropylmercapturic acid

FINANCIAL DISCLOSURE: Dr Benowitz is a consultant to several pharmaceutical companies that market medications to aid smoking cessation and has served as a paid expert witness in litigation against tobacco companies. Drs Ramo and Rubinstein have consulted for Carrot Inc, which makes a tobacco cessation device; and Dr Delucchi has indicated he has no financial relationships relevant to this article to disclose.

FUNDING: Funded by National Institutes of Health (NIH) grants R21DA040718, P50 CA180890, P30 DA012393, S10 RR026437, and TRDRP 24XT-0007. Funded by the National Institutes of Health (NIH).

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Pediatrics originally published online March 5, 2018;

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Pediatrics originally published online March 5, 2018;

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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Villanti et al. BMC Public Health (2017) 17:983
DOI 10.1186/s12889-017-4987-z

BMC Public Health

RESEARCH ARTICLE Open Access

Menthol cigarettes and the public health standard: a systematic review

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Abstract

Background: Although menthol was not banned under the Tobacco Control Act, the law made it clear that this did not prevent the Food and Drug Administration from issuing a product standard to ban menthol to protect public health. The purpose of this review was to update the evidence synthesis regarding the role of menthol in initiation, dependence and cessation.

Methods: A systematic review of the peer-reviewed literature on menthol cigarettes via a PubMed search through May 9, 2017. The National Cancer Institute's Bibliography of Literature on Menthol and Tobacco and the FDA's 2011 report and 2013 addendum were reviewed for additional publications. Included articles addressing initiation, dependence, and cessation were synthesized based on study design and quality, consistency of evidence across populations and over time, coherence of findings across studies, and plausibility of the findings.

Results: Eighty-two studies on menthol cigarette initiation ($n = 46$), dependence ($n = 14$), and cessation ($n = 34$) were included. Large, representative studies show an association between menthol and youth smoking that is consistent in magnitude and direction. One longitudinal and eight cross-sectional studies demonstrate that menthol smokers report increased nicotine dependence compared to non-menthol smokers. Ten studies support the temporal relationship between menthol and reduced smoking cessation, as they measure cessation success at follow-up.

Conclusions: The strength and consistency of the associations in these studies support that the removal of menthol from cigarettes is likely to reduce youth smoking initiation, improve smoking cessation outcomes in adult smokers, and in turn, benefit public health.

Keywords: Cessation, Dependence, Policy, Youth tobacco use, Public health

Background

Menthol has been added to tobacco products as a characterizing flavor since at least the 1920s, but many of the current menthol brands were introduced in the mid-1950s [1, 2]. In 2013, the most recent year of data from the Federal Trade Commission, menthol cigarettes represented 30% of the cigarette market [3]. Tobacco companies have also noted that the menthol segment of the market continues to grow [4], including Reynolds American and Philip Morris USA who have continued to expand their distribution of menthol cigarettes in the past year [5].

The Tobacco Control Act banned all candy and fruit flavors as characterizing flavors of cigarettes. The law did not include menthol in that ban, nor did it address flavors in non-cigarette tobacco products [6]. However, the Act makes clear that the Food and Drug Administration (FDA) has the authority to issue a product standard to ban menthol in cigarettes, or any other tobacco product, to protect public health. In fact, the Act required the Tobacco Product Scientific Advisory Committee (TPSAC), as its first order of business, to review the state of the science on menthol and make a recommendation to the FDA based on the public health standard [7]. TPSAC undertook a review of the science and issued a comprehensive report concluding that it would be in

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the interest of public health to remove menthol cigarettes from the market [8]. Further, FDA, conducted an independent review of the science in 2013. This report concluded that it is "likely that menthol cigarettes pose a public health risk above that seen with non-menthol cigarettes" [9].

The purpose of the current review was to update the state of the evidence on menthol in cigarettes with respect to two of the three key elements of the public health standard: first, whether there is an increased or decreased likelihood that those who do not currently use tobacco products, most notably youth, will start to use tobacco products; and second, whether there is an increased or decreased likelihood that existing users of tobacco products will stop using such products [10]. In addition to providing a third independent summary of the evidence on menthol, this study highlights findings published after the FDA's 2013 review.

Methods

We undertook a systematic review using a PubMed search of the peer-reviewed literature through May 9, 2017 with the terms "menthol AND cigarette*." The National Cancer Institute's Bibliography of Literature on Menthol and Tobacco [11] and the FDA's original 2011 report [9] and 2013 addendum [12] were reviewed for additional publications not captured in the PubMed search. Articles published prior to 2013 were reviewed for inclusion and coded by AV; articles published after 2013 were reviewed for inclusion by LC and coded by LC and AV. In 2016, the review was moved into a centralized database and searches were rerun within Eppi-Reviewer 4 (EPPI-Centre, University of London); at this time, all abstracts were double-checked against the inclusion criteria for quality control purposes. The May 2017 search update was conducted within the Eppi-Reviewer platform. Lab-based studies and studies with no direct comparison between menthol and non-menthol use were excluded. Published reviews, commentaries, case reports, editorials, letters to the editor, meeting proceedings, and policy statements were also excluded. Included studies were classified into at least one of 6 categories, including 1) Initiation; 2) Dependence; 3) Cessation; 4) Prevalence; 5) Marketing; and 6) Policies.

Since the main goal of the current review was to update a narrative review on the Initiation, Dependence, and Cessation categories and a range of study types were included, we did not employ a standardized assessment of the quality of included studies (e.g., PRISMA checklist). To synthesize the evidence for these three categories, we:

(1) Examined the methods and designs of the studies, the rigor with which they were conducted, and the limits of interpreting data with respect to the population, place, and time of the study;
(2) Categorized individual studies according to their methods and design and evaluated studies that used comparable methods to determine consistency of the evidence across populations and over time. We examined evidence across these comparable studies to assess the strength of the association and to determine if a temporal relationship was present between menthol cigarette use and smoking initiation or cessation;
(3) Evaluated the body of scientific evidence to determine whether findings of individual studies were coherent with each other and with our broader understanding of tobacco use in the United States; and
(4) Considered the plausibility of these findings in the context of tobacco industry and related documents.

Finally, we asked whether positive associations exist and whether chance, bias, and confounding could be ruled out with reasonable confidence. In keeping with a classification scheme based on FDA's public health standard, and recognizing that decision-makers must often act in the face of scientific uncertainty, we asked whether the evidence in a particular area was sufficient to conclude that a relationship was more likely than not, whether the evidence shows that a relationship was at least as likely as not, whether the evidence is insufficient to conclude that a relationship was more likely than not, or whether there was insufficient evidence to make a determination of strength of evidence. The focus of the evidence synthesis was on studies conducted in the United States; data presented from other countries is noted as such throughout the text.

Results

Of the 131 empirical articles on menthol cigarettes included in the full review (see Fig. 1), 82 were relevant to initiation ($n = 46$; Additional file 1: Table S1), dependence ($n = 14$; Additional file 2: Table S2), and cessation ($n = 34$; Additional file 3: Table S3). The remaining 49 articles addressed other topics: prevalence ($n = 13$), marketing ($n = 22$), and policies ($n = 14$). Thirty-three of these articles were published after 2013. Details on the findings by study category are described in detail below.

Initiation

The prevalence of menthol cigarette use is higher in youth than young adults and adults

A 2015 study using 2004–2010 data from the National Survey on Drug Use and Health (NSDUH), adjusted for misclassification of menthol brand, showed that from 2008 to 10, 56.7% of youth smokers (aged 12–17)

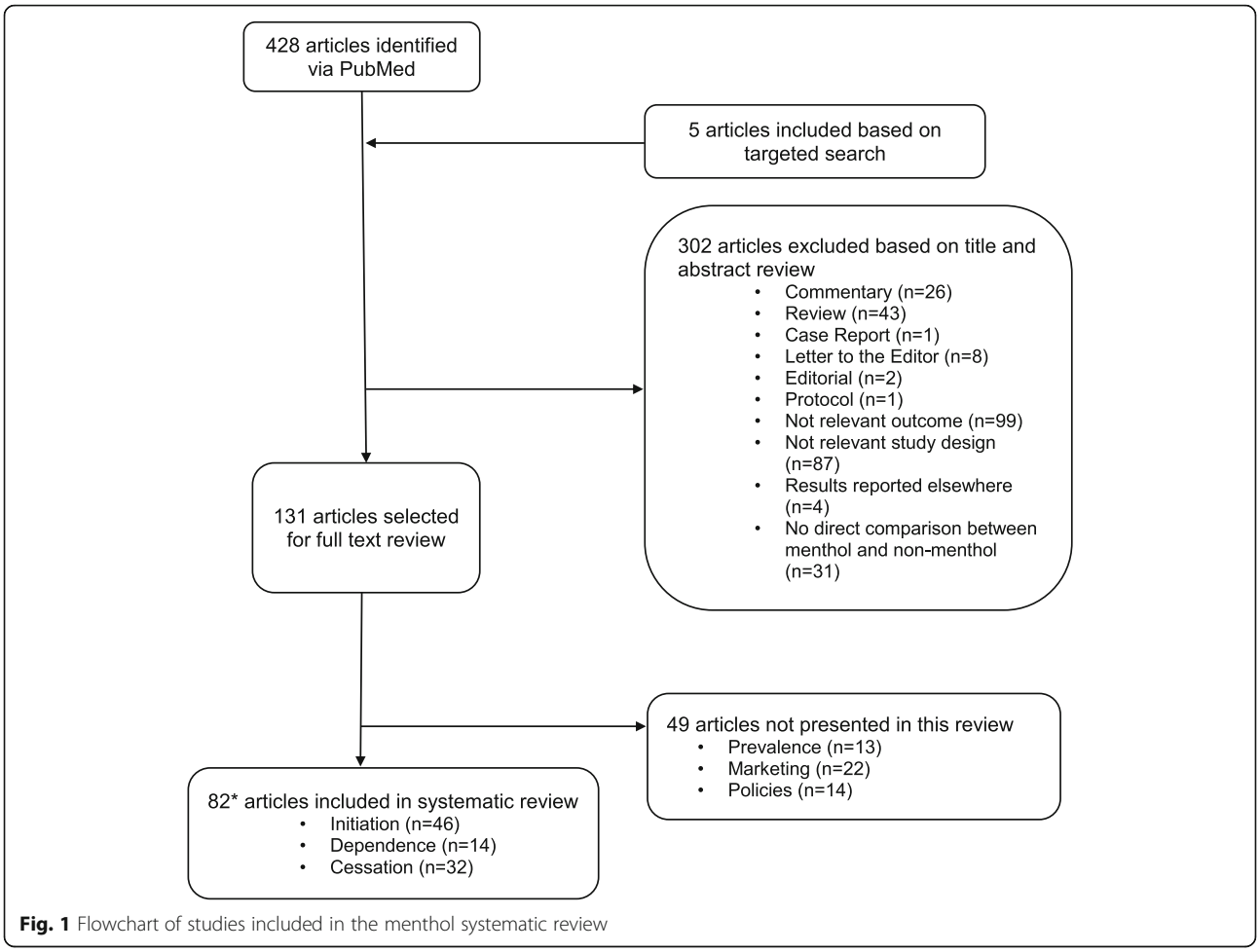

Fig. 1 Flowchart of studies included in the menthol systematic review

smoked menthol cigarettes [13]. This compares with an overall menthol cigarette prevalence (youth and adults) of 35.2% and represents 1.2 million menthol smoking youth. A 2016 follow-up study in NSDUH highlighted that the percentage of menthol cigarette smokers increased 4.1 percentage points between 2008–2010 and 2012–2014, with youth smokers remaining the age group with the highest prevalence of menthol cigarette use [14]. These findings were also confirmed using 2013–2014 data from the Population Assessment of Tobacco and Health (PATH) Study [15]. Among current cigarette smokers, 59.5% of youth used mentholated cigarettes compared to 37.1% of adults. When looking only at exclusive cigarette smokers, the prevalence of mentholated cigarette use remained higher in youth (56.5%) compared to adults (39.5%).

Black smokers report a high prevalence of menthol cigarette use, regardless of age [13, 16–21]. A cross-sectional study of adult daily smokers found that nearly 80% of black smokers smoked menthol cigarettes, the highest prevalence across racial/ethnic groups [22]. Controlling for gender, race/ethnicity, household income and days smoked in the past month, the odds of smoking mentholated brands were more than three-fold higher in the youngest age groups (12–15 and 16–17) of smokers compared to smokers aged 35 and older in both 2008–2010 [13] and 2012–2014 [14]. These estimates are slightly higher than those published in the 2009 *NSDUH Report: Use of Menthol Cigarettes* [16] and NSDUH analyses by Caraballo and Asman [19] and Rock et al. [18], but account for two more years of data collection and adjustment for misclassification of menthol status. Together, these studies demonstrate the stability of these nationally-representative estimates over seven years highlighting higher rates of menthol use in youth compared to adults from 2004 to 2014.

There is a persistent age gradient in menthol cigarette use among the youngest smokers

Results from the 1999, 2000, and 2002 National Youth Tobacco Survey (NYTS), a survey administered to approximately 25,000 middle and high school students in each wave, confirm a statistically significantly higher prevalence of menthol cigarette use among middle

school students compared to high school students [23–25]. Results differ for some racial/ethnic subgroups [26, 27]. In the 2006 NYTS, 57.1% of middle school smokers reported that their usual brand was menthol compared to 43.1% of high school smokers [28]. Data combined for years 2004, 2006, and 2009 of the NYTS showed that 49.4% of middle school current smokers reported smoking menthol cigarettes compared to 44.9% of high school current smokers [19]. In 2004 and 2006 NYTS, Newport was the second most popular brand among youth smokers [29].

Studies of youth and adults published prior to 2013 highlight that the highest prevalence of menthol cigarette use occurs among youth smokers, followed by young adult smokers, and that both are significantly higher than menthol cigarette use among older adult smokers [17–19]. These findings are consistent with studies using more recent data that were published after 2013 [13–15, 30].

Other recent national studies examining adults only consistently report that young adult smokers (aged 18–24 or 18–25) are significantly more likely to use menthol cigarettes than older adult smokers (aged 25+ or 26+), even after controlling for other potential confounders including socioeconomic status, sexual orientation [31], and psychological distress [32]. One study in a national sample of young adults aged 18–34 found that menthol cigarette smokers were significantly younger than non-menthol cigarette smokers in bivariate analyses, but this did not persist in multivariable models, likely due to the restricted age range of the sample [33].

Menthol cigarette use among youth has not decreased in the past decade, despite decreases in non-menthol cigarette use

Giovino et al. showed that the prevalence of smoking menthol cigarettes remained constant among youth (aged 12–17) from 2004 to 2010, at the same time that the prevalence of non-menthol cigarette use decreased significantly in this age group [13]. Furthermore, menthol cigarette use significantly increased over this time period in young adults (aged 18–25) while the prevalence of non-menthol cigarette use decreased significantly. These findings were consistent with the 2011 NSDUH report on *Recent Trends in Menthol Cigarette Use* [17]. In updated NSDUH data from 2014, menthol cigarette prevalence was higher than non-menthol cigarette prevalence in youth and young adults [14].

Recent youth initiates are significantly more likely to use menthol cigarettes than youth who have smoked longer than one year

Estimates from the NYTS and NSDUH also demonstrate increased menthol cigarette use among recent youth initiates. Two studies [16, 34] combining waves of national data on youth smoking report a higher prevalence of menthol cigarette use among youth who have been smoking less than one year compared to those who have smoked more than one year. One of the studies combined data from five years of the NSDUH (2004–2008) and the other used two years of data from the NYTS (2000 and 2002). In the NSDUH study, past month smoking of menthol cigarettes was more likely among smokers aged 12–17 who began smoking in the past 12 months than among those who had been smoking for more than a year (49.2% vs. 43.8%); findings were similar in young adults where past-year initiates had higher menthol use than longer-term smokers (40.2% vs. 36.4%) [16]. The 2011 NSDUH report on menthol also reported that the prevalence of menthol use in recent initiates among all participants aged 12+ increased during 2007–2010 as compared to 2004–2006 and that past month menthol use was higher among recent initiates compared to longer-term smokers in both time periods [17]. In the NYTS study, middle school students who had been smoking for less than 1 year were significantly more likely to smoke menthol cigarettes compared with middle school students who had been smoking for more than 1 year (62.4% vs. 53.3%, $p = 0.002$) [34]. Two recent analyses in the NYTS data [19, 28] did not find a significant relationship between menthol cigarette use and smoking initiation among adolescents. One study using 2006 NYTS data shows that the proportion of middle school smokers whose usual brand was menthol was higher among those who smoked for 1 year or more (54.7%) than among those who smoked for less than a year (42.2%) [28]. Among high school youth, these percentages were similar for smokers who had smoked for less than and for more than 1 year (42.8% vs. 43.1%). Another study combining data across years of the NYTS (2004, 2006, and 2009) used cigarettes smoked per day and days smoked per month as proxy measures for early "stages" of use (initiation) and showed no difference in the prevalence of menthol use by "stage" [19].

Longitudinal studies demonstrate that initiation with menthol cigarettes facilitates progression to established use in young smokers

Prior to 2014, one cross-sectional study and two longitudinal studies assessed the impact of menthol initiation on smoking behavior. Conducted in a southeastern city, the cross-sectional study showed that black middle and high school students, who smoke at lower rates than whites, greatly accelerate their cigarette consumption when their brand of choice contains menthol [35]. African American menthol users were between 1.7 and 3.5 more likely to fall into a higher category of cigarette

consumption than whites. A longitudinal study, conducted by Nonnemaker et al. [36], documents that adolescents who initiated smoking with menthol cigarettes during the course of a cohort study were more likely to progress to established smoking by the end of the three-year study compared to those who initiated with non-menthol cigarettes. The stringency of the definition of "established smoking" in this study (i.e., at least 100 cigarettes lifetime plus smoking on 20–30 of the past 30 days) provides strong evidence for the relationship between menthol cigarette use and progression to regular use given the typical adolescent definition of current cigarette use as any use in the past 30 days. The second longitudinal study, published by Dauphinee et al. [37] shows that recognition of Newport cigarettes, a leading menthol brand, was associated with smoking experimentation in a large sample of adolescent never-smokers at 12-month follow-up.

Findings from four recent cross-sectional studies further support these findings. One cross-sectional study of a nationally-representative sample of Canadian high school students showed that menthol smoking youth had a significantly higher odds of reporting intent to continue smoking compared to non-menthol smoking youth [38]. These findings held when examining established and experimental smokers separately. A second cross-sectional study examined changes in smoking behavior using a national sample of young adult smokers and showed that menthol cigarette use nearly doubled the odds of increased smoking behavior, including transitioning from no smoking to current smoking or from someday to every day smoking in the past year [39]. These findings are consistent with recent analyses in Wave 1 of the PATH study that documented a strong association between first use of a flavored tobacco product and current tobacco use among youth and adults [15]. A fourth cross-sectional study, which conducted regression analyses using data from four nationally representative samples of youth and adult current smokers, found that current menthol use was not associated with an increased odds of being a daily versus non-daily smoker in youth and adults [40].

Young smokers are likely to remain with their "starter" type of cigarette over time

Data from the National Youth Smoking Cessation Survey (NYSCS), a two-year (2003–2005) longitudinal telephone study of adolescent and young adult cigarette smokers aged 16–24 confirm that 85% of baseline menthol smokers remained menthol smokers at 24 months and 93% of baseline non-menthol smokers remained non-menthol smokers [41]. In a study published in 2013 by Nonnemaker et al., the majority of adolescent smokers who initiated with menthol cigarettes remained menthol smokers at follow-up (63%); this was similar to the proportion of adolescent smokers who initiated with non-menthol cigarettes and remained with non-menthol smokers at follow-up (62%) [36].

Two studies published after 2013 support these findings. One study, conducted over one year in the Truth Initiative Young Adult Cohort, bolsters the findings that the majority of young adult smokers, aged 18–34, remain with their initial type of cigarette over time [42]. In this study, young adults smokers who initiated with menthol cigarettes were more than eight times more likely to remain menthol cigarette smokers than those who initiated with non-menthol cigarettes. The second study, focused more broadly on flavored tobacco use in Wave 1 of the PATH study, found first use of a flavored tobacco product was associated with a more than two-fold higher prevalence of exclusive menthol cigarette use in adults, with young adults being more likely to use menthol cigarettes [15].

The findings regarding an age gradient in menthol cigarette use – Increased levels of menthol smoking in the youngest age groups – are not attributable to menthol brand misclassification or socioeconomic status

Misclassification of menthol cigarette use has been identified in youth studies [28] and tobacco control researchers have also raised the notion that menthol cigarette use may be associated with economic pressure to use fewer cigarettes [43], thus menthol use may be due to lower socioeconomic status. These data show that the age gradient in use is not an artifact of misclassification of menthol use [23]. They also highlight that use of menthol cigarettes is not explained by socioeconomic status, assessed as household income.

Four papers published after 2013 confirm these earlier results. Analyses using 2008–2009 NSDUH data support that young adults (aged 18–25) are significantly more likely to use menthol cigarettes than older adults, after controlling for age, gender, race/ethnicity, education, income, marital status, health insurance, cigarettes per day, time to first cigarette, and psychological distress [32]. Giovino et al. addressed potential misclassification of menthol brand among youth and adults in 2008–2010 NSDUH data, showing a persistent age gradient in menthol cigarette use across gender, race/ethnicity, household income, and number of days smoked per month [13]. These findings held in updated analyses of 2012–2014 NSDUH data [14]. A fourth study published in 2016 using 2012–2013 NSDUH data showed that menthol cigarette use was also not explained by urban/rural differences [44].

Menthol cigarette smoking is correlated with other risk behaviors in young people

Menthol cigarette smoking has been associated with other tobacco use in young adults (small cigars [45] and other flavored tobacco products [46]) and alcohol and

marijuana use in youth [47–49]. In a community-based sample of adolescents in the U.S., past 30-day menthol cigarette smokers reported higher lifetime marijuana use, but not marijuana use in the past 30 days compared to non-menthol smokers [48]. In a sample of adolescent daily smokers seeking cessation treatment, menthol cigarette use was correlated with past 30-day marijuana use [48].

In a nationally-representative sample of Canadian 7th through 12th grade students published after 2013, menthol cigarette smokers were significantly more likely to report binge drinking or using marijuana in the past year compared to non-menthol smokers [47]. In national NSDUH data collected in 2013 and 2014 among participants aged 12 and older, a higher percent of marijuana/menthol cigarette users were 12–17 years of age compared to other usage groups (i.e., marijuana/non-menthol cigarettes, menthol cigarettes only, non-menthol cigarettes only) [49].

The tobacco industry has long understood the appeal of menthol cigarettes as starter products for youth

Historical tobacco industry documents underscore menthol brands as starter products for youth (i.e., "Menthol brands have been said to be good starter products because new smokers appear to know that menthol covers up some of the tobacco taste and they already know what menthol tastes like, vis-à-vis candy" [50]) and recognize the importance of adolescent smokers to the success of menthol brands (i.e., "The success of Newport has been fantastic during the past few years. Our profile taken locally shows this brand being purchased by black people (all ages), young adults (usually college age), but the base of our business is the high school student" [51]). Recent tobacco industry document reviews have also underscored the relationship between menthol cigarette use, youth smoking initiation and tobacco dependence, as understood and manipulated by the tobacco industry [52–54]. Data from financial analysts support that the menthol marketplace is strongly influenced by youth smoking. Tobacco industry experts at Morgan Stanley noted in 2012 that menthol cigarettes continue to have a higher market share in younger age groups, despite the fact that youth smoking continues to decline [55]. Increased market share of menthol cigarettes among youth has also been documented outside the U.S. [56, 57].

In two studies published after 2013, the appeal of menthol flavoring was demonstrated to influence intention to smoke and initial smoking [58, 59].

Summary - initiation

Fifteen years of national studies of tobacco use across different populations and time periods arrive at the same conclusions: there is a strong pattern of a higher – and growing – proportion of menthol cigarette use among youth (aged 12–17) than adults, and especially among younger adolescents and recent youth initiates. The results from large, representative studies provide evidence of an association between menthol and youth smoking that is robust and consistent in magnitude and direction and is unlikely to be due to bias, confounding, or chance. Among all youth and young adults, not just current smokers, the prevalence of smoking non-mentholated brands decreased from 2004 to 2014; as of 2014, menthol cigarettes were more prevalent than non-menthol cigarettes in youth and young adults, indicating that menthol cigarettes are gaining market share in these age groups.

More particularly, the replication of these findings over time using different studies and populations provides evidence of consistency. Data showing a high prevalence of menthol use among youth, in addition to higher prevalence among younger adolescents and recent initiates, and stable or increasing menthol cigarette use over time – despite reductions in non-menthol cigarette use – supports coherence of the evidence on menthol and youth smoking. Plausibility of the relationship between menthol and youth smoking is corroborated by historic industry and related documents on the development and marketing of mentholated cigarettes to youth [50, 51]. The magnitude and statistical significance of the data on the increasing proportion of menthol use and brand preference among youth over time reveals that this is a national phenomenon. Additional analyses exclude misclassification and socioeconomic status as explanations for the high prevalence of menthol cigarette use among youth.

Dependence

Youth menthol smokers report greater levels of nicotine dependence than youth non-menthol smokers

Of eight studies assessing nicotine dependence among youth [28, 34, 36, 60–64], five demonstrate significantly higher endorsement of dependence symptoms among menthol smokers compared to non-menthol smokers [28, 34, 36, 60, 62]. Of the three studies using NYTS data from 2000, 2002, 2004, and 2006, two [28, 62] report that young menthol cigarette users have a significantly shorter first time-to-cigarette after waking, which is a hallmark of nicotine dependence [65], after adjusting for gender, race, grade, number of days smoked in the past 30 days and number of cigarettes smoked per day. These two studies also show greater endorsement of withdrawal symptoms among youth menthol smokers, particularly, craving [28, 62], and feeling irritable or restless after not smoking for a few hours [28]; these findings also adjusted for gender, race, grade, number of

days smoked in the past 30 days and number of cigarettes smoked per day. This is consistent with the third NYTS paper that highlights higher than median scores on a nicotine dependence scale among youth menthol compared to non-menthol smokers, controlling for age, gender, race/ethnicity, and smoking behavior (i.e., length, frequency, and level of smoking) [34]. A smaller cross-sectional study of adolescents recruited for a cessation treatment study by Collins and Moolchan also reported a greater proportion of adolescent menthol smokers smoking within five minutes of waking compared to non-menthol smokers [60]. Further, a national longitudinal study of U.S. adolescents reported that initiating smoking with menthol cigarettes was associated with higher nicotine dependence score, controlling for gender, age, race/ethnicity [36]. Two of the remaining three studies showed no differences in adolescent nicotine dependence in menthol versus non-menthol smokers using the Hooked on Nicotine Checklist [61, 63]. The third study, which used data from four nationally representative samples of youth and adults, found that menthol smokers do not report a higher Heaviness of Smoking Index, compared to non-menthol smokers [64].

Adult menthol smokers report shorter time to first cigarette than non-menthol smokers

Six studies in adults also focus on nicotine dependence among menthol compared to non-menthol smokers by assessing time to first cigarette [6, 66–70]. Two studies in women show that female menthol smokers have a significantly shorter time to first cigarette than non-menthol smokers [66, 68]. A study in a sample of current daily smokers from 1990 to 2001 reported a significantly shorter time to first cigarette among Black menthol users compared to non-menthol users, but this relationship was not present among White smokers [67].

Two studies in adult current smokers published after 2013 found no significant difference in time to first cigarette between menthol and non-menthol cigarette smokers [69, 70]. However, one other study was more aligned with earlier findings. The study of adult daily smokers found that menthol smokers were significantly more likely to report that they would hate to give up the first cigarette in the morning more than any other compared to non-menthol smokers [6].

Summary - dependence

Of fourteen studies published over a fifteen-year period, nine show that menthol smokers report increased nicotine dependence compared to non-menthol smokers [6, 28, 34, 36, 60, 62, 66–68]. The data on dependence among youth menthol smokers are particularly strong, given that four [28, 34, 36, 62] of the five studies showing an association control for a number of important confounders and one of these documents a temporal relationship between initiation with menthol cigarettes and the subsequent development of a higher level of nicotine dependence compared to initiation with a non-menthol cigarette [36]. All six of the studies in adults are cross-sectional, of which four demonstrate a shorter time-to-first cigarette among menthol smokers compared to non-menthol smokers. Three of these four studies examine women [66, 68] and Blacks [67], both groups targeted by tobacco industry marketing [71].

The findings on increased nicotine dependence among youth and adults are particularly important because they highlight a potential mechanism linking experimentation with cigarettes through progression to regular use, and subsequently, reduced cessation among menthol smokers. As a result, it is very likely that a ban on menthol in cigarettes would reduce nicotine dependence at the population level, thus having tremendous impacts on both initiation and cessation of cigarette use.

Cessation

In examining evidence on the relationship between menthol cigarette use and smoking cessation, we focused on studies that used cessation measures in addition to measures of quit attempts or intention to quit; as a result, there are several studies using intention to quit or quit attempts as the primary outcome that are not addressed in detail in this section [42, 72–74].

National cross-sectional studies

Five studies in the Tobacco Use Supplement to the Current Population Survey (TUS-CPS) measure cessation outcomes beyond quit attempts or intention to quit. Three studies [75–77] demonstrate that menthol users are less successful in quitting than non-menthol users despite increased quit attempts or intentions to quit. One of these studies found that past-year quit attempts were significantly increased in menthol compared to non-menthol smokers, but short-term (greater than 3 months and less than one year) and longer-term (greater than 3 months and less than five years) quit rates were significantly lower among those who smoke menthol cigarettes as compared to non-menthol cigarettes [75]. One study exploring cessation by race/ethnicity reported that non-Hispanic white, African American, and Puerto Rican menthol smokers were less likely to have quit smoking in the past five years compared to their non-menthol smoking counterparts [76]. Another study examining cessation by racial/ethnic groups found that cessation of at least six months was significantly reduced by 52% to 78% in African American, Hispanic/Latino, Asian American/Pacific Islander, and non-Hispanic white menthol smokers compared to non-menthol smokers [77]. Two studies found no

difference in cessation outcomes among menthol and non-menthol smokers [78, 79]. One study examined quitting behaviors among daily menthol and non-menthol smokers with similar cigarette consumption patterns and found no difference in quit attempts or greater than two-week abstinence by menthol status [78]. One study published after 2013 among current and past-year smokers (recent active smokers) found no difference in quit intention, quit attempts, or quit rate among menthol compared to non-menthol smokers [79].

Studies of adult smokers in the 2005 National Health Interview Survey (NHIS) Cancer Control Supplement corroborate the findings for reduced cessation among racial and ethnic subgroups from the TUS-CPS data. These studies report increased quit attempts in the past year among menthol compared to non-menthol smokers [80, 81] but significantly reduced cessation among African-American [80, 82] and Hispanic menthol smokers compared to non-menthol smokers [82]. One of these studies [82] also collapsed Hispanic and African-American smokers into one category and reported a statistically significant decrease of 45% in the odds of cessation among non-White menthol smokers compared to non-White non-menthol smokers. One study assessing quit duration as a cessation measure showed that there was a significant increase in quit duration among white female menthol smokers compared to white female non-menthol smokers, but no statistically significant differences among the other five demographic groups [81].

A more recent study examined the association between menthol use and the likelihood of being a former versus current smoker using data from the TUS-CPS (2010/11) and the NHIS (2005 and 2010). Analyses of the TUS-CPS found a statistically significant inverse association between menthol use and having quit smoking, but this was not reported when using the NHIS [83].

Community-based studies

One study from 1981 to 1999 in a hospital-based study of 19,545 current and former smokers showed that Black and White menthol users were significantly less likely to be former smokers compared to non-menthol users, but was no longer significant after controlling for age, sex, education, case–control status, years of smoking, and cigarettes per day [84]. Another study of 480 inner-city adult current smokers reported that menthol smokers reported a more recent quit attempt compared to non-menthol smokers (12 vs. 24 days; $p = 0.047$), but there was no difference in most recent or longest ever duration of abstinence [85]. A third study of 928 female smokers screened for a smoking cessation study reported that fewer menthol smokers reported a previous quit attempt of greater than 90 days compared to non-menthol smokers [68]. In a hospital-based study of 1067 adult smokers there was no significant effect of menthol use on motivation to quit and confidence to quit when adjusting for age, sex, race, income, education, and tobacco dependence [86].

Cohort studies

Of eight cohort studies examining differences in smoking cessation [87–94], three reported significantly lower quit rates among menthol smokers compared to non-menthol smokers at follow-up [90, 91, 94]. The study by Pletcher et al. [90] showed a 37% reduction in the odds of sustained cessation adjusted for age, sex, and ethnicity, but this result did not retain statistical significance after additional adjustment for educational level, marital status, employment, and health insurance status. The second study by Gandhi et al. [91] reported significant reductions in the odds of cessation of 68% and 57% among African American and Latino menthol smokers, respectively, at 4-week follow-up and a decrease of 52% in African Americans at 6-month follow-up, controlling for age in years, education, gender, employment status, type of insurance, cigarettes per day, age smoked for first time, awaken at night to smoke, time to use first cigarette of day, previous attempts to quit smoking, and the presence of a disease caused or aggravated by smoking. The third study published in 2014 by Lewis et al. [94] found menthol smokers to be less likely to quit (17.1% in African Americans, 24.2% in non-African Americans) than non-menthol smokers (21.9% in African Americans, 29.4% in non-African Americans).

Two additional studies by Reitzel et al. showed significant reductions in cessation in White menthol smokers, adjusted for covariates including age, partner status, income, and education; one for long-term (approximately 6 months) continuous abstinence in pregnant smokers [87] and a more recent publication for short-term abstinence in adult daily smokers [93]. Three other studies did not show a difference in abstinence at follow-up in menthol compared to non-menthol smokers [88, 89, 92]. The COMMIT study [89], which did not show a difference in cessation between menthol and non-menthol smokers, surveyed smokers in selected communities in the U.S. and Canada between 1988 and 1993. Possible reasons for the mixed results across the three studies include population sampling and recentness of the data.

Of the five studies showing a statistically significant difference in cessation by menthol smoking status, one [91] was conducted in a cessation clinic population from 2001 to 2005, one [90] in a large cohort of healthy young African American and European American men and women in four US cities from 1985 through 2000, one [94] in a sample of nationally representative U.S.

households from 2004 to 2009, and two others in community-based samples in Houston, Texas between 2004 and 2008 [87, 93]. The two other studies showing no effect of menthol on cessation were conducted in southern States from 2002 to 2009 [92] and in Minnesota between 2009 and 2011 [88]. We would note that the cigarette market has undergone dramatic changes over the past 10–15 years, including the introduction of a number of new menthol brands. Because of the differences in menthol levels and effects among brands [95], it is important to rely on the most recent data that reflects products currently on the market. Accordingly, we consider the COMMIT study less relevant to the question of adult cessation in the context of an FDA ban on menthol, as it includes older data. Additional weight should also be given to the cohort study conducted in a cessation clinic [91], as it reflects smokers who are motivated to quit and thus, controls for confounding by cessation cognitions and intention to quit.

Randomized controlled trials

Seven randomized controlled trials [96–102] in populations motivated to quit smoking explored the impact of menthol cigarette use on cessation. One study testing the impact of a phone survey and provider progress notes on smoking cessation among VA patients showed no difference six months after the intervention in smokers who had not smoked in the past seven days [96]. An additional study among stimulant-dependent adults found no significant association between cigarette type and smoking cessation [100]. However, five studies [97–99, 101, 102] testing the effect of pharmacotherapies and behavioral therapies on smoking cessation reported significantly reduced cessation among menthol smokers compared to non-menthol smokers. While results in two of these studies [97, 98] maintained a consistent direction (i.e., menthol users had reduced cessation compared to non-menthol users), they were not statistically significant across all follow-up time points; three of these studies reported significantly reduced cessation among menthol smokers at all time points assessed [99, 101, 102]. In the 2003 study by Okuyemi et al. [97], African American menthol smokers had significantly reduced 7-day point prevalence abstinence at 6 weeks (28.3% vs. 41.5%; $p = 0.006$) compared to African American non-menthol smokers, but the difference was not significant at 6 months (21.4% vs. 27.0%; $p = 0.21$). In the 2007 study of African American light smokers (≤ 10 cigarettes per day) by Okuyemi et al. [98], menthol smokers had significantly reduced 7-day point prevalence abstinence at 26 weeks (11.2% vs. 18.8%; $p = 0.015$) compared to non-menthol smokers, but not at 8 weeks (22.6% vs. 26.8%; $p = 0.291$). The 2013 study of African American light smokers by Faseru et al. [99] showed significantly reduced cotinine-verified 7-day point prevalence abstinence among menthol compared to non-menthol smokers at week 7 (14.4% vs. 28.4%; $p = 0.001$) and week 26 (10.0% vs. 20.4%; $p = 0.005$); this study also demonstrated an 84% increased odds of cessation among non-menthol compared to menthol smokers, controlling for treatment, visit attendance, cotinine level, and years smoked. In the 2014 study of treatment–seeking smokers by Rojewski et al., [101] menthol smokers showed significantly reduced 7-day point prevalence abstinence among menthol compared to non-menthol smokers at week 14 (14.8% vs. 33.3%; $p = 0.04$) and week 26 (13% vs. 30%; $p = 0.04$). In the 2014 study by Smith et al. [102], menthol smoking was associated with reduced likelihood of smoking cessation success compared to non-menthol smoking (31% vs. 38%); this study also found that among menthol smokers, African American women were at a particularly high risk of cessation failure compared to white women (17% vs. 35%; OR = 2.63, 95% CI = 1.75,3.96). One major difference in these studies is focus of the cessation intervention.

Five studies [97–99, 101, 102] testing the impact of an individual-level intervention showed reduced cessation among menthol smoking participants while the provider-focused intervention [96] showed no difference in cessation among menthol and non-menthol smoking participants. One individual-level intervention did not show a difference in cessation by menthol use, but that may be attributed to its unique population and the effect of smoking on the participants' other substance use. The studies focusing on individual-level interventions are more relevant to the question of menthol's influence on smoking cessation, as they capture a seven to eight-week window of evidence-based treatment for smoking cessation rather than a single provider visit. The five studies of African American [97–99, 102] and treatment-seeking [101] smokers provide particularly strong evidence of reduced cessation among menthol compared to non-menthol smokers in the face of extended smoking cessation treatment.

Summary - cessation

Four of five studies in the TUS-CPS [75–77, 83] and two of four studies in the Cancer Control Supplement to the National Health Interview Survey [80, 82] that examined quit attempts and additional cessation measures among adult smokers indicate that cessation is reduced in non-Hispanic whites and in racial and ethnic subgroups of menthol smokers compared to non-menthol smokers despite increased quit attempts. These findings demonstrate reasonable consistency and a coherent picture of quit behavior among menthol smokers: menthol smokers make more quit attempts than non-menthol smokers, yet have a more difficult time quitting

successfully. Five [87, 90, 91, 93, 94] of eight cohort studies and five [97–99, 101, 102] of seven randomized controlled trials contribute to the consistency of the findings and the strength of the association between menthol smoking and reduced cessation among adult smokers. Evidence from these ten studies with consistent results also support the temporal relationship between menthol smoking and reduced smoking cessation through their study designs which included longitudinal follow-up of adult smokers. One community-based cross-sectional study also indicates that female menthol smokers have reduced cessation success [68]. One study using consumer purchasing data also shows that African American menthol smokers are less likely to quit smoking [94]. Further, these findings are plausible in light of historic tobacco industry marketing of menthol cigarettes as medicinal, less harmful, or even a more healthful product than non-menthol cigarettes [103–106] and the resulting perceptions among menthol smokers that menthol cigarettes may be less risky than regular cigarettes [107]. These population-based cross-sectional, cohort, and randomized controlled studies, which showed strong and consistent associations between menthol use and reduced smoking cessation, were high quality, and addressed bias and confounding through regression adjustment or randomization.

Discussion

Studies published after 2013 bolster and augment earlier findings regarding the deleterious relationship between menthol cigarette use, youth smoking initiation, and nicotine dependence. The strength and consistency of the associations in these studies confirm the conclusions of previous studies and provide additional support for the conclusion that an FDA ban on menthol tobacco products would benefit public health.

Limitations of this review include restriction of the search to articles published in PubMed and lack of multiple independent coders which may have biased the way that studies were included and characterized. Additionally, brand names (e.g., Newport) were not included in the search strategy, which may have resulted in not capturing all relevant studies.

Studies of the cigarette marketplace confirm menthol's growing market share. The proportion of menthol variants of popular brands like Pall Mall, Camel, and Marlboro rose, at times substantially, between 2004 and 2013 [108]. Newport, the leading menthol brand, increased its market share from 7.23% in 2002 to 10.89% in 2013 [108] and has continued to grow following Reynolds American's 2015 acquisition of Lorillard Tobacco Company [109], from 13% to 13.6% in the fourth quarter of 2015 alone [110]. More recently, Newport launched new promotional efforts aimed at recruiting young adults to smoke cigarettes [111].

Analyses of the NSDUH highlight that among past 30-day smokers, the proportion of menthol cigarette users was 35% in 2008–2010 and increased significantly to 39% in 2012–2014 [14]. These increases were observed in young adults aged 18–25, as well as adults aged 26–34 and 35–49 and over this time period, youth smokers aged 12–17 remained the group with the highest prevalence of menthol cigarette use (54%) [14]. The findings of this review, in concert with recent evidence on the increasing presence of menthol in the cigarette market, underscores the urgent need for policy action to ban the sale, marketing, or presence of menthol as a characterizing flavor in cigarettes at the national, state, and local levels.

Conclusions

This review of the scientific evidence demonstrates that there is more than sufficient evidence to establish a positive relationship between menthol cigarettes and (1) increased youth smoking initiation, (2) increased nicotine dependence, and (3) decreased adult cessation. The weight of the evidence from studies published through 2017 supports that removal of menthol from cigarettes would, in the words of the Tobacco Control Act, decrease the likelihood that those who do not use tobacco products will start using such products and increase the likelihood that existing users of tobacco products will stop using such products.

Additional files

Additional file 1: Table S1. Characteristics of included studies on menthol cigarettes and smoking initiation. Table including Reference, Study Design, Setting, Study Population, Sample Size, and Outcomes (DOCX 67 kb)

Additional file 2: Table S2. Characteristics of included studies on menthol cigarettes and nicotine dependence. Table including Reference, Study Design, Setting, Study Population, Sample Size, and Outcomes (DOCX 33 kb)

Additional file 3: Table S3. Characteristics of included studies on menthol cigarettes and smoking cessation. Table including Reference, Study Design, Setting, Study Population, Sample Size, and Outcomes (DOCX 57 kb)

Abbreviations

FDA: Food and Drug Administration; MTF: Monitoring the Future; NHANES: National Health and Nutrition Examination Survey; NHIS: National Health Interview Survey; NSDUH: National Survey on Drug Use and Health; NYSCS: National Youth Smoking Cessation Survey; NYTS: National Youth Tobacco Survey; PATH: Population Assessment of Tobacco and Health; TPSAC: Tobacco Product Scientific Advisory Committee; TUS-CPS: Tobacco Use Supplement to the Current Population Survey

Acknowledgements

The authors thank Ellen J. Vargyas, JD for her feedback on an earlier draft of this manuscript.

Funding
Funding for this review was provided by Truth Initiative. AV was supported by in part by Truth Initiative, the Tobacco Centers of Regulatory Science (TCORS) award P50DA036114 from the National Institute on Drug Abuse and Food and Drug Administration (FDA), and the Centers of Biomedical Research Excellence P20GM103644 award from the National Institute on General Medical Sciences. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health or the Food and Drug Administration. The funders had no role in the design of the study, data collection, analysis, interpretation of data, or writing the manuscript.

Availability of data and materials
All data generated or analysed during this study are included in this published article and its Additional files.

Authors' contributions
AV conceptualized the review, conducted the initial search of the literature, and drafted the manuscript. AV and LC conducted additional searches of the literature and updated the manuscript. SG, RN, and DA provided guidance throughout the process and critical revisions on the manuscript drafts. All authors read and approved the final manuscript.

Ethics approval and consent to participate
Not applicable

Consent for publication
Not applicable

Competing interests
The authors declare that they have no competing interests.

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Received: 21 June 2017 Accepted: 10 December 2017
Published online: 29 December 2017

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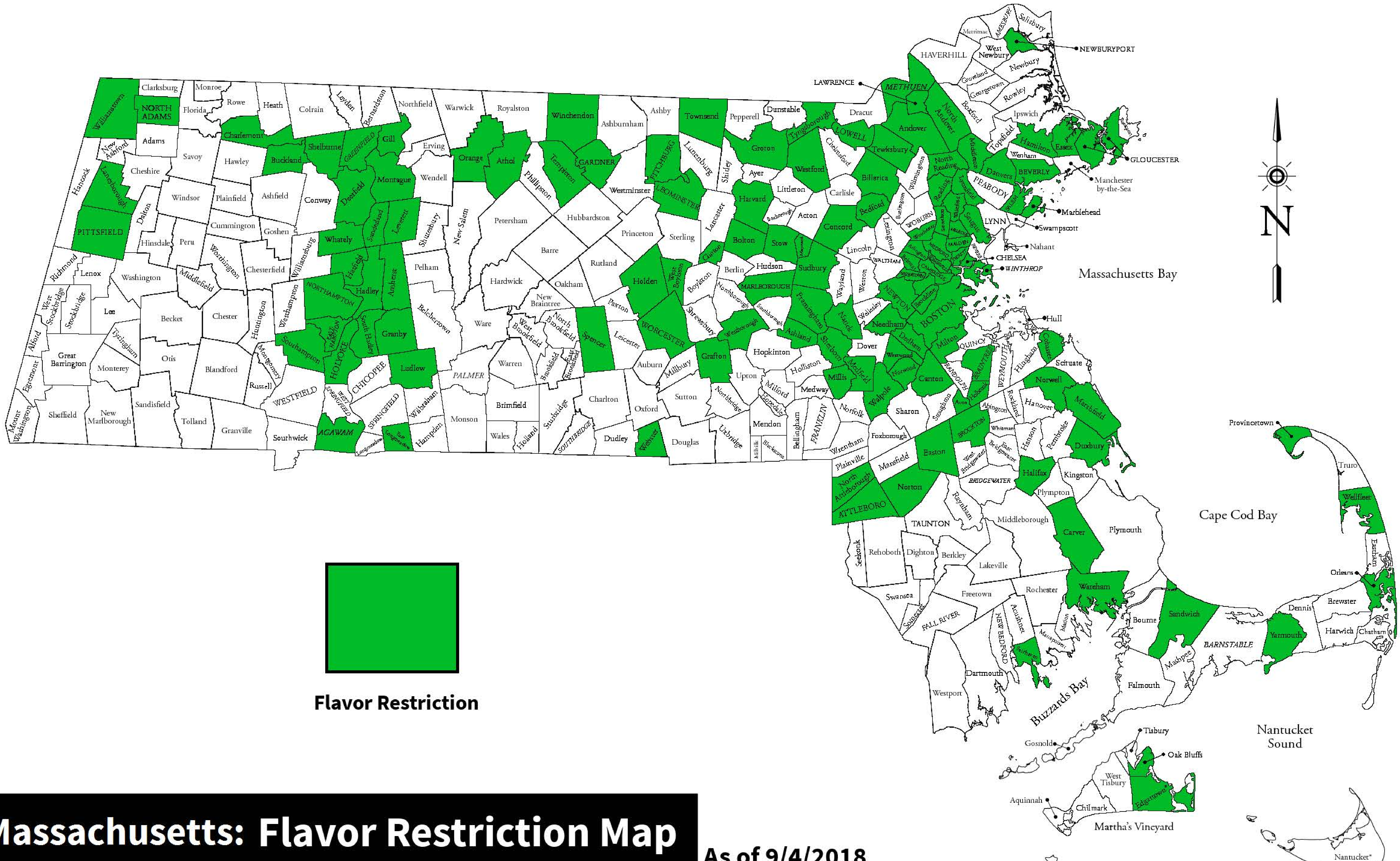


Massachusetts: Flavor Restriction Map

As of 9/4/2018

JUUL and Youth: Rising E-Cigarette Popularity

What is a JUUL?

The term "electronic cigarettes" covers a wide variety of products now on the market, from those that look like cigarettes or pens to somewhat larger products like "personal vaporizers" and "tank systems." Instead of burning tobacco, e-cigarettes most often use a battery-powered coil to turn a liquid solution into an aerosol that is inhaled by the user. One e-cigarette device, called a JUUL, has become increasingly popular since its launch in 2015.

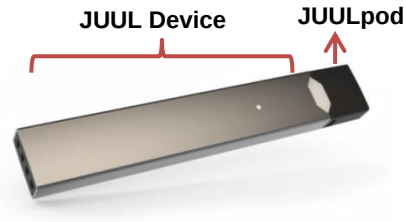


Image from JUUL website, accessed 1/24/18

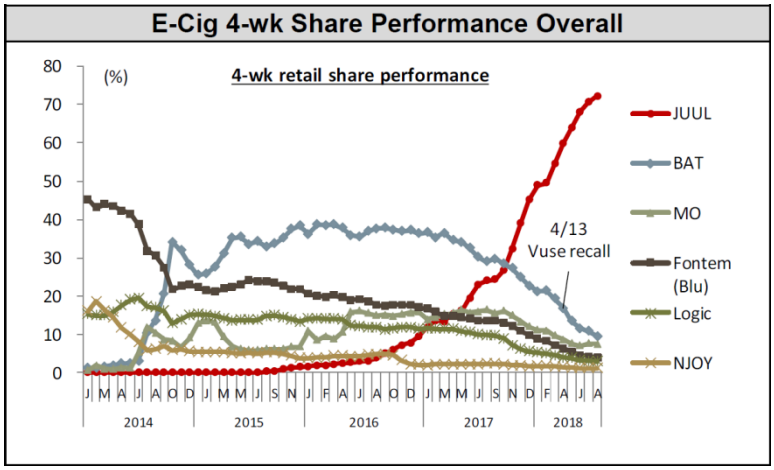
JUULpods. Image from JUUL website, accessed 1/24/18

JUUL device charging in the USB port of a laptop. Image from JUUL website, accessed 1/24/18.

JUUL Labs produces the JUUL device and JUULpods, which are inserted into the JUUL device. In appearance, the JUUL device looks quite similar to a USB flash drive, and can in fact be charged in the USB port of a computer. According to JUUL Labs, all JUULpods contain flavorings and 0.7mL e-liquid with 5% nicotine by weight, which they claim to be the equivalent amount of nicotine as a pack of cigarettes, or 200 puffs. JUULpods come in five flavors: Cool Mint, Crème Brulee, Fruit Medley, Virginia Tobacco, Mango, as well as three additional limited edition flavors: Cool Cucumber, Classic Tobacco, and Classic Menthol.[1] Other companies manufacture "JUUL-compatible" pods in additional flavors; for example, the website Eonsmoke sells JUUL-compatible pods in Blueberry, Silky Strawberry, Mango, Cool Mint, Watermelon, Tobacco, and Caffé Latte flavors.[2] There are also companies that produce JUUL "wraps" or "skins," decals that wrap around the JUUL device and allow JUUL users to customize their device with unique colors and patterns (and may be an appealing way for younger users to disguise their device).

JUUL skins. Images from https://www.mightyskins.com/juul/

According to data from Wells Fargo, JUUL's popularity has grown dramatically in the last year, with unit sales increasing more than 600 percent in 2017. In mid-2016, dollar sales share for JUUL products was less than 5 percent, the lowest compared to products sold by the main companies in Nielsen-tracked channels.* But by the end of 2017, JUUL sales had surpassed all other companies' products (see adjacent graph).[3] As a result, JUUL is now more popular than the e-cigarette brands manufactured by the major tobacco companies (blu, Vuse, and MarkTen). According to the most recent data from Wells Fargo, JUUL sales currently represent 72% of the market share.[4] As JUUL has surged in popularity, other companies have sought to mimic JUUL's



Source: Nielsen Total US xAOC/Convenience Database & Wells Fargo Securities, LLC

* Tracked data includes mass channel and convenience stores; does not include online sales or sales from tobacco and vape shops.

sleek design and pod-based system, with new devices such as MLV's PHIX, Mylé Vapor's Mylé, Altria's Markten Elite, Reynolds' Vuse Solo, and ITG Brands' myblu.[5]

JUUL Use among Youth and Young Adults

According to the National Youth Tobacco Survey, 11.7 percent of high school students and 3.3 percent of middle school students—over 2.1 million youth—were current e-cigarette users in 2017.[6] However, a study from Truth Initiative found that a quarter of youth and young adult JUUL users don't refer to JUUL use as "e-cigarette use" or "vaping," but rather as "JUULing."[7] Therefore, it is possible that existing surveys may not be capturing the full spectrum of youth e-cigarette use. News articles, letters from school officials, and anecdotal evidence indicate that JUUL has gained popularity among youth and young adults across the country, from middle schools to college campuses. A 2018 study found that nearly one-fifth of youth (ages 12-17) surveyed reported having seen JUUL used in their school.[8] News stories attribute JUUL's sleek and discreet design to its appeal among this population. For example:

> *"High school and college students are rushing to retailers to buy the product because its discreet design makes it easy to hide from parents and teachers while also giving the user a big hit of nicotine. Some students have bragged on social media of using the JUUL in class, even though e-cigarettes are banned indoors at most schools."* – Pittsburgh Post-Gazette[9]

> *"An editor for New York University's student newspaper documented JUUL's rising on-campus popularity, even in dorm rooms. A student newspaper at the University of Illinois called JUUL a "new epidemic is sweeping across campus." And in suburban D.C., a high school's principal took doors off its bathroom stalls to keep students from using drugs inside —namely JUUL."* – USA Today[10]

> *"One reason JUUL and vape pens are so popular among teens currently might be that they can be used indoors without attracting unwanted attention or creating a stench…On Twitter, teens post about their usage in school. The most brazen of them fire up their e-cigarettes while their teachers' backs are turned."* - NPR[11]

The availability of flavors may also contribute to JUUL's popularity among youth. A national survey found that that 81 percent of youth aged 12-17 who had ever used e-cigarettes had used a flavored e-cigarette the first time they tried the product, and that 85.3 percent of current youth e-cigarette users had used a flavored e-cigarette in the past month. Moreover, 81.5 percent of current youth e-cigarette users said they used e-cigarettes "because they come in flavors I like." [12]

Health Concerns and JUUL

The number of youth using e-cigarettes, including JUUL, is alarming and raises serious concerns that e-cigarettes could be an entryway to nicotine addiction and use of regular cigarettes for some kids. Though there is insufficient research on the long-term effects of using e-cigarettes in general, and certainly not specific to JUUL, the use of such products still raises concerns because they contain nicotine. The company claims that the nicotine in JUUL is from "nicotine salts found in leaf tobacco, rather than free-base nicotine," which they claim "accommodate cigarette-like strength nicotine levels."[13] The health impact of that specific form of nicotine is yet unknown.

While it is still an open scientific question whether e-cigarettes might be able to help adult smokers give up cigarettes, kids should not be using any tobacco product, including e-cigarettes. Nicotine is a highly addictive drug that can have lasting damaging effects on adolescent brain development.[14] Nicotine also impacts the cardiovascular system.[15] The Surgeon General concluded that, "The use of products containing nicotine poses dangers to youth, pregnant women, and fetuses. The use of products containing nicotine in any form among youth, including in e-cigarettes, is unsafe."[16] Educating youth about the dangers of JUUL and nicotine use is critical because a study from Truth Initiative found that 63 percent of 15-24 year old JUUL users did not know the product always contains nicotine (all pods sold from JUUL do contain nicotine).[17]

The Surgeon General found that while more research is needed, evidence from several longitudinal studies suggests that e-cigarette use is "strongly associated" with the use of other tobacco products among youth and young adults, including conventional cigarettes.[18] The National Academy of Sciences

(formerly the Institute of Medicine) also concluded in its 2018 report that, "There is substantial evidence that e-cigarette use increases risk of ever using combustible tobacco cigarettes among youth and young adults."[19]

Marketing and Accessibility of JUUL

JUUL billboard in Times Square, New York City, 2015. https://www.spencer-pederson.com/work-1/2017/2/23/juul-go-to-market

When JUUL was first launched in 2015, the company used colorful, eye-catching designs and youth-oriented imagery and themes, such as young people dancing and using JUUL. JUUL's original marketing campaign included billboards, YouTube videos, advertising in Vice Magazine, launch parties and a sampling tour.

More recently, JUUL has updated its marketing code[20] with the purported goal of limiting youth exposure to its advertising. Its current marketing materials focus primarily on its popular flavors and on messaging that encourages smokers to "make the satisfying switch." However, social media continues to help fuel JUUL's popularity. A study analyzing JUUL marketing noted that JUUL was one of the first major e-cigarette brands to rely heavily on social media to market and promote its products. The study found that JUUL's initial marketing expenditures in traditional channels were modest compared to competing brands, and that these expenditures decreased as the brand increased content and received more promotion on social media channels like Instagram and Twitter.[21] While JUUL's Instagram account is age-restricted to those 18 and older, its Twitter account is not age restricted and contains similar content. Additionally, JUUL-sponsored posts and user-generated posts that tag (e.g., #JUULvapor, #doit4JUUL) and feature JUUL have no restrictions. These kind of social media posts can increase exposure to pro-e-cigarette imagery and messaging, by making JUUL use look cool and rebellious. In April 2018, the FDA sent an official request for information to JUUL Labs to obtain more information about the youth appeal of the product, including the company's marketing practices.[22]

JUUL devices and JUULpods are available for sale on JUUL's website and other online retailers as well as in convenience stores, vape shops, and tobacco retailers. To access JUUL's website, users must indicate that they are 21 or older by simply clicking on a button, but JUUL asserts that it uses stricter age verification processes for online purchases. FDA law prohibits sales of e-cigarettes to those under age 18 and some state and local laws have higher minimum age-of-sale laws. Youth are obtaining JUUL products from social sources who may be over age 18, online or in-person from retailers that are not in compliance with state or federal law, or from online resellers like ebay[†] and Craigslist that have no age verification. A 2018 study found that among surveyed youth JUUL users (ages 12-17), three-quarters had purchased a JUUL device from a retail store and half had gotten JUUL from a social source.[23] In April 2018, the FDA sent warning letters to 40 retailers across the country for illegally selling JUUL products to minors.[24] Though the up-front cost of the device is high (a JUUL starter kit, which includes the device, charger and 4 JUULpods, is $49.99 on the JUUL website), advocates have shared stories of kids pooling together money to share a device and sell "hits" from the device to recoup the cost.

JUUL Twitter Post. January 9, 2018. https://twitter.com/JUULvapor/status/950890455499231235

Campaign for Tobacco-Free Kids, August 21, 2018 / Laura Bach

[†] ebay policy prohibits sale of tobacco products; however, JUUL products have been found for sale on the website under other categories such as electronics, with product listings that neglect to use the terms "tobacco" and/or "nicotine." FDA recently contacted ebay regarding these violations and ebay has worked to remove JUUL listings and implement measures to prevent new JUUL listings (although some JUUL products are still available on ebay).

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Board of Health

Kathleen Ward Brown, ScD
Member

Edward Cosgrove, PhD
Vice Chair

Stephen Epstein, MD, MPP
Chair

Mission

The Needham Board of Health, founded in 1877, and its Public Health Division strive to prevent and control the spread of disease, to address environmental issues, to promote healthy lifestyles, and to protect the public health and social well-being of all Needham's residents, especially the most vulnerable.

Goals FY 2019 and 2020

Administrative

Ensure the necessary infrastructure to effectively provide essential public health services.

- Develop a Public Health Division-wide communications strategy that incorporates a variety of methods (articles, videos, presentations to community groups, hosting of community forums) to ensure community outreach on pertinent public health issues.
- Continue to pursue small grant funding opportunities to meet distinct community needs (similar to concussion education, and healthy aging initiatives).
- Continue to enhance and refine financial tracking mechanisms to ensure complete and appropriate use of municipal, grant, and donated financial resources.
- Develop processes and accrue resources to support the continual gathering of qualitative and quantitative data to inform the activities of the Public Health Division, and the larger Health & Human Services Department.
- Build capacity to conduct a community needs assessment, including a town-wide complete health survey.
- *Long-term* - Pursue Public Health Division accreditation and support the establishment of a culture of continuous quality improvement.

DRAFT

Community Health

Increase the quality, availability, and effectiveness of educational and community-based programs designed to prevent disease and injury, improve health, and enhance quality of life.

- Emphasize the importance of affordable and accessible housing as a public health issue for all Needham's residents and especially for the Town's senior citizens
    - Explore an accessory dwelling unit bylaw change.
- Advocate for resources to support and enhance Healthy Aging in the community, such as accessible senior housing and more frequent forms of town or community-run transportation programs.
- Advocate for resources to enhance community transportation options, especially for older adults and low income populations.
- Continue and expand the Safety at Home Program, which addresses older adult falls through home visits, exercise programming, and referrals, and identify resources to financially support more comprehensive home modifications.
- Provide additional health and education services for vulnerable populations, such as Housing Authority residents, based on the outcomes of targeted assessments.
- Support existing community initiatives that address public health concerns including senior nutrition, elder isolation, mental health promotion, and domestic violence awareness.
- Sustain multi-disciplinary work to assist families and community members in need of mental health, domestic violence, and substance use support through the Needham Community Crisis Intervention Team (CCIT).

Emergency Management/Emergency Preparedness

Improve the community's ability to prevent, prepare for, respond to, and recover from a major emergency.

- Increase the operating budget funding devoted to Emergency Management such that it will support a full-time professional along with expense costs for publications, trainings, and drills and exercises without relying on fluctuating external funding sources.
- Revise and update the Town's Comprehensive Emergency Management Plan (CEMP) to include implementation of procedures for internal and external communications, Incident Command System (ICS), and workplace redundancy to improve the Town's Continuity of Operations.

DRAFT

- Continue to update municipal safety and emergency guidelines by implementing building specific emergency procedures and train and drill employees annually on those procedures.
- Revise, educate, and test, by means of an annual drill or exercise, Emergency Dispensing Site protocols and plans, aligning with MA DPH and CDC requirements.
- Emphasize community outreach to inform residents about the importance of personal preparedness, helping your neighbor - especially those with access and functional needs, and the promotion of Town communications and emergency notification systems.
- Revise and enhance Needham's Medical Reserve Corps through volunteer recruitment, training, and retention.
- Achieve full certification of the Needham Local Emergency Planning Committee (LEPC) through the Massachusetts Emergency Management Agency's State Emergency Response Commission.
- *Long-term* - Deploy volunteers during emergencies in another community requesting assistance at least once per year, and expand Needham's coverage for volunteers during emergencies in a manner that allows for the most effective use of those volunteer resources.

Environmental Health (EH)

Promote health for all through a healthy environment

- Hire additional staff or provide additional resources to maintain EH Unit capacity for inspections, environmental health monitoring, training, and vendor and general public education.
- Prioritize positive communication and relationships with food service owners and staff and tobacco vendor owners and staff.
- Continue to work toward meeting all nine (9) FDA Voluntary National Retail Food Regulatory Program Standards; pursue federal, state, and non-profit grant resources to offset the costs for achieving full compliance and apply for future FDA grants to make this possible.
- Implement FDA Standard 9 through categorization of Needham food establishments and use of risk-based inspections
- Research best practices and pursue regulatory standards for posting of calorie counts and nutritional information.
- Develop regular schedule for detailed review and revision of all regulations, and conduct a comprehensive assessment of regulations which require updates, revisions, or which should be rescinded by the end of FY 2019.

DRAFT

- Fully implement electronic food inspection technology, and utilize capabilities for advanced analysis of food service establishment compliance and violations to identify topics for education and vendor education.
    - Expand electronic inspection system and utilize for at least one other environmental health inspection (pools, septic, housing, etc.) by the end of FY 2020.
- *Long-term* - Develop and implement food establishment grading policies.
- *Long-term* - Research options for digital record keeping and, in conjunction with the Town's IT Department and other partners, pursue a joint online permit application and permit granting system.
    - When online system is implemented, investigate options for electronic payment for permits and fees and implement an electronic payment system.

Public Health Nursing

Advance population health through quality community/ public health nursing education, research and service.

- Annually examine community demographics and population needs to identify priorities for public health nursing staff activities.
- Continue work to address the needs of the aging population through prevention efforts and education including home safety visits, blood pressure and other wellness clinics, and mental health services and referrals.
- Evaluate implementation of summer camp regulations.
- Evaluate the cost and capabilities of the Needham Health Division in regards to flu vaccination and education. Monitor how the town uses different outlets for flu vaccination.
- Develop processes and protocols in collaboration with community partners to access Needham Health DVAC resources.
- Work with the Aging Services Division and with the Youth & Family Services Division to develop processes and protocols for CCIT. Create a process for an annual community outreach calendar of focused educational and training programs such as sunscreen, tick borne illnesses, summer camps, and other timely public health issues.
- Operationalize new Massachusetts Department of Public Health's guidance for Emergency Dispensing Sites by end of FY 2019.

DRAFT

Substance Use Prevention

Reduce substance use and misuse to protect the health, safety, and quality of life for all, especially children.

Needham

- Provide at least six (6) educational and/or informational events to the Needham community about adverse health impacts of substance use and misuse for the youth, adult, and/or senior populations by June of 2020.
    - After each event, administer an evaluation that will be used to qualitatively measure performance.
- Cooperatively with the Needham Police Department and public health and law enforcement partner agencies in Dedham, Norwood, and Westwood, formalize alcohol compliance checks and conduct them semi-annually (FY 2019 and FY 2020) with the eventual goal of quarterly inspections (FY 2021).
- Draft and implement a policy for Needham that outlines specific consequences to alcohol vendors who fail compliance checks in order to decrease youth access to alcohol by decreasing alcohol vendor compliance failures from 6 to 4 by 2020.
- Research and develop regulations for Needham that will govern the use of recreational marijuana.
- Revise existing regulations that govern medical marijuana. The overall goal of such regulations should be to ensure the safe and sanitary operations of marijuana dispensaries and recreational marijuana establishments, while at the same time educating the community about the dangers of chronic use and general misuse of marijuana, and promoting a safe and healthy environment for all of Needham's residents.
- Increase availability of proper prescription medication disposal options and secure storage practices within the Town of Needham.
    - *Long-term* - Establish a third safe and secure disposal location in Needham for prescription medications (in addition to current medication disposal kiosks at the Police Station and at Beth Israel Deaconess-Needham Hospital).
    - *Long-term* - Secure a second safe and secure location in Needham for a sharps disposal kiosk at another Town facility or a community partner agency (FY 2021 approximately).
    - *Long-term* - Decrease access to prescription medications in Needham by the end of 2020 by hosting two (2) additional mobile take backs per year, in addition to the spring and fall Take Back Days on Town Common.
        - Increase weight of semi-annual prescription medication disposal in Needham (inclusive of all disposal locations) by at least 5%.

DRAFT

- *Long-term* - Decrease Needham High School's 30 day youth use rates for alcohol, misuse of prescription drugs, and marijuana, by 2% by June 2021. This will be measured by comparing the 2016 MetroWest Adolescent Health Survey (MWAHS) results with the 2018 and 2020 MWAHS results.

Regional SAPC Cluster (Needham, Dedham, Norwood and Westwood)

- Address parental attitudes favorable to use through a community awareness and education campaign in Needham, Dedham, Norwood and Westwood using messaging based on research including materials such as AD Council PSAs, SAMHSA Talk They Hear You, MADD Power of Parenting, Boston Children's Hospital Teen-Safe.org.
- Address low perception of harm among high school grade 9 students by instituting a policy in Needham, Dedham, Norwood and Westwood school systems that 9th grade parents take AlcoholEdu High School Parents 30-minute on-line course.
- Identify social and community norms by organizing a Photo Voice project with youth leaders from each community to monitor collect, and track the number of Needham, Dedham, Norwood and Westwood alcohol related examples of social, athletic and fundraising events and media advertising depicting active promotion of a normative drinking culture, visible to youth.
- Conduct Retail TIPS- Responsible Beverage Service training for licensees in Needham, Dedham, Norwood and Westwood to reduce ease of access to alcohol in the four communities.
- Conduct a community awareness & education campaign in Needham, Dedham, Norwood and Westwood to encourage people lock up alcohol in their homes in the 4 communities.

DRAFT

Board of Health

Kathleen Ward Brown, ScD
Member

Edward Cosgrove, PhD
Vice Chair

Stephen Epstein, MD, MPP
Chair

Policy Position: Accessory Dwelling Units

The Needham Board of Health believes changing the Town's bylaws to allow accessory dwelling units is aligned with the Board's mandate from the Massachusetts General Court to protect the public health and wellness of the Town of Needham and all its residents. [1,2]

Needham lacks affordable, available, accessible, age-friendly housing. Over 50% of Needham seniors state that they would consider moving out of Needham due to the high cost of housing, while over 90% state it is somewhat, very, or extremely important for them to remain in Needham as they age. [3]

Affordable, high-quality housing is linked to improved health. For example, when living in an affordable home, individuals can put more money towards nutritious food and health care, rather than housing. Additionally, stable, affordable housing reduces stress and improves mental health. [4]

One approach to mitigate this issue is allowing accessory dwelling units. Accessory dwelling units – also known as "in-law" apartments – are defined as "a self-contained apartment in an owner-occupied single family home that is either attached to the principal dwelling or in a separate structure on the same property". [5]

Accessory dwelling units can be beneficial because they:

- Increase housing options while maintaining the physical character of the town
- Provide moderately-priced homes
- Help young and older adults and people with disabilities stay in town as their needs change
- Increase revenue: for homeowners through rental income; for the Town through greater tax revenue generated by added value to existing homes
- Decrease isolation and depression as older adults remain in the town where they have connections and live close to others [6]

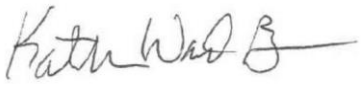
DRAFT

The Needham Board of Health recognizes the 68 cities and towns around Boston that have allowed ADUs in some capacity and stands with the Center for Housing Policy, AARP, and the Metropolitan Area Planning Council, among others, in support of accessory dwelling units.[6] The Needham Board of Health agrees with a report for Needham's Public Health Division which states accessory dwelling units "are a low-impact, high-value way to address the problem of diminishing housing options".[7]

This Policy Position was formally adopted following a unanimous vote during a noticed public meeting, October 18, 2018.

Edward Cosgrove, PhD
Vice Chair

Stephen Epstein, MD, MPP
Chair



Kathleen Ward Brown, Sc.D.
Member

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[1] M.G.L. ch. 111, s.31, available at: https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXVI/Chapter111/Section31
[2] M.G.L. ch. 111, s.122, available at: https://malegislature.gov/Laws/GeneralLaws/PartI/TitleXVI/Chapter111/Section122
[3] Needham Council on Aging and Needham Public Health Department. Assessment of Housing and Transit Options for Needham Seniors. 2016.
[4] Maqbool N, Viveiros J, Ault M. The Impacts of Affordable Housing on Health: A Research Summary. Center for Housing Policy. 2015. Available: https://www.rupco.org/wp-content/uploads/pdfs/The-Impacts-of-Affordable-Housing-on-Health-CenterforHousingPolicy-Maqbool.etal.pdf
[5] Massachusetts Executive Office of Energy and Environmental Affairs. Smart Growth/ Smart Energy Toolkit: Model Bylaw for Accessory Dwelling Units. (n.d.) Available: http://www.mass.gov/envir/smart_growth_toolkit/bylaws/ADU-Bylaw.pdf
[6] Dain A. The State of Zoning for Accessory Dwelling Units. Pioneer Opportunity. 2018. White Paper No. 184. Available: https://pioneerinstitute.org/economic_opportunity/study-boston-area-communities-should-loosen-restrictions-for-accessory-dwelling-units/
[7] Miara C. Accessory Dwelling Units: A Report for Needham Public Health Division. 2017.

MEMORANDUM

TO: TIMOTHY MCDONALD
DIRECTOR OF HEALTH & HUMAN SERVICES
TOWN OF NEEDHAM

FROM: RICHARD LESTER

SUBJECT: RESPONSE TO QUESTIONS – WEST ROXBURY TO NEEDHAM RELIABILITY PROJECT

DATE: OCTOBER 11, 2018

CC: KATE FITZPATRICK, RAY MIYARES, RICHARD MERSON

At the request of the Town of Needham (the "Town"), I have reviewed electromagnetic field modeling for the proposed West Roxbury to Needham Reliability Project (the "Project"). I write to offer responses to three questions received from a concerned citizen with respect to the Project. I understand that the questions were received from a resident in the vicinity of South Court, but the answers are relevant to the entire proposed Project.

How much EMF will the transmission line produce?

Electromagnetic fields (EMF) are produced whenever a current flows through a transmission line. EMF is also produced by electric currents on wires within homes and in the vicinity of operating appliances. The physics of modeling EMF is very well understood, and it is straightforward to model electric and magnetic fields produced by electric current flowing on a transmission line using software designed for that purpose. Though I have not performed a detailed review of the modeling performed by Gradient Corporation for the Project, I have reviewed the results of the modeling, and the results are consistent with what I have seen at other similar projects.

Transmission lines produce both electric and magnetic fields. Underground lines do not produce measurable above ground electric fields. Only magnetic fields will be detectable above ground in the vicinity of the Project. Magnetic field strength is measured in units of milligauss, abbreviated mG. As a point of comparison, the earth's natural magnetic field in Needham has a strength of approximately 519 mG. The earth's magnetic field is a static field, meaning that it is always in the same orientation. This is why compass needles always point north. Magnetic fields associated with the Project will be much less strong than the earth's magnetic field, but differ in that they will alternate direction 60 times each second, corresponding to the fact that electricity in the United States is transmitted at a frequency of 60 hertz (abbreviated Hz). It is because the magnetic fields change direction that the magnetic field associated with transmission lines can be distinguished from the earth's magnetic field. 60 Hz magnetic fields (those associated with electricity use) are generally less than 10 mG in residences, but can be more than 100 mG in close proximity to operating appliances that use large amounts of electricity such as electric blankets,

hair dryers, and toasters. The most typical 60 Hz magnetic field levels in residences in the middle of rooms, away from wiring, range from 0.1 to 3 mG.

The magnetic fields produced by the Project will vary depending on the amount of current on the transmission line (the "load"). For this reason, Gradient's modeling evaluates magnetic fields at peak load (the maximum load that will be present on the lines) and at the annual average load. The load on the line on any given day depends on many factors, and it is not possible to predict with certainty when the load will be greatest, but in general, transmission line loads are frequently high in the afternoon of very hot summer days when air conditioning use and electricity use are greatest.

Magnetic field levels associated with the Project will be greatest immediately above the transmission line in the street. Magnetic field levels will decrease rapidly with distance from the line. At peak summer loads, the modeled magnetic field strength above the transmission line in its standard configuration is 71 mG. This field strength falls to 7.1 mG at a distance of 20 feet from the center of the transmission line. At the annual average load on the transmission line, the modeled magnetic field strength directly above the line is 33 mG, falling to 3.6 mG at a distance of 20 feet from the centerline.

How much EMF will be produced at manholes without shielding?

Magnetic fields in the vicinity of manholes will differ from those along the rest of the line. Modeled magnetic fields in the vicinity of manholes at peak load are 98.6 mG directly above the line and fall to 20 mG at a distance of 20 feet. Modeled magnetic fields in the vicinity of manholes at the annual average load are 46 mG and fall to 9 mG at a distance of 20 feet.

What is the health standard for magnetic fields produced by the Project?

The International Commission on Non Ionizing Radiation Protection (ICNIRP) has developed a health-based guideline for public exposure to 60 Hz magnetic fields. The ICNIRP guideline is 2,000 mG. Magnetic fields generated by the Project will be far less than this guideline.

While there are no other health-based standards for comparison, the Massachusetts Energy Facilities Siting Board has frequently used a guideline of 85 mG at the edge of a ROW when deciding whether to site a new transmission line. This is not a health-based standard or guideline, and it is applied at the edge of a right-of-way, not directly above or beneath a transmission line. Modeled project magnetic fields are less than 85 mG at all locations except for within approximately 5 feet of a manhole at peak load.

A significant amount of scientific research has been conducted examining whether long-term 60 Hz magnetic field exposure can be linked to childhood leukemia. This research has been conducted because a review of many studies looking at childhood leukemia suggested that there may be a two-fold increase in childhood leukemia at 60 Hz magnetic field levels greater than 4 mG. The World Health Organization (see the fact sheet at http://www.who.int/peh-emf/publications/facts/fs322/en/) has examined this literature and concluded that there are potential problems with the scientific studies and that it cannot be concluded that low frequency (60 Hz) magnetic fields cause childhood leukemia. Scientific research is still being conducted in this area. Because no causal relationship has been established, no health-based standards have been developed based on childhood leukemia.

In the vicinity of South Court, the nearest residences are approximately 35 feet from the edge of South Street. At a distance of 35 feet from the transmission line, average (long-term) magnetic field strengths associated with the Project are modeled to be less than 4 mG both near the transmission line and in the vicinity of manholes.

Please contact me at 857-366-2015 or richlester@gmail.com should you have any questions or wish to discuss these responses further.

Health Department to host flu clinics

The Needham Health Department will be hosting the following seasonal flu clinics:

Thursday, September 20

Center at the Heights (300 Hillside Ave)

1:00 – 4:00 p.m.

Wednesday, September 26

Rosemary Recreation Complex (178 Rosemary St)

11 a.m. – 2:00 p.m.

Wednesday, October 10

Rosemary Recreation Complex (178 Rosemary St)

11 a.m. – 2:00 p.m.

Saturday, October 20

Center at the Heights (300 Hillside Ave)

9:00 a.m. – Noon

Needham Health Department clinics are for those 18 years and older. Attendees are asked to bring all insurance cards, Medicare cards included, as the Department will be billing insurance.

The Needham Public Health Department will be offering subsequent seasonal influenza vaccine clinics. For questions, call the Needham Public Health Department at (781-455-7940, x217) or visit www.needhamma.gov/health.

Needham Health Department releases flu, flu clinic info

Posted Sep 11, 2018 at 12:20 PM
Updated Sep 11, 2018 at 12:20 PM

The Needham Health Department will host the following seasonal flu clinics:

1-4 p.m. Sept. 20 at the Center at the Heights, 300 Hillside Ave., Needham.

11 a.m.-2 p.m. Sept. 26 at the Rosemary Recreation Complex, 178 Rosemary St., Neetdham.

11 a.m.-2 p.m. Oct. 10 at the Rosemary Recreation Complex, 178 Rosemary St., Needham.

9 a.m.-noon Oct. 20 at the Center at the Heights, 300 Hillside Ave., Needham.

The health department's clinics are for those 18 years and older. Please bring all insurance cards, Medicare cards included, as the department will be billing insurance.

Influenza, known as flu, is a very contagious disease of the respiratory system. The flu is caused by a virus that is easily passed from one person to another by coughing and sneezing. For most people, the flu makes them feel very sick, but they generally get better in about a week. However, young children, people older than 65 years of age, pregnant women and people with chronic medical conditions can have serious complications from the flu. These complications can include pneumonia, dehydration and worsening of medical conditions like heart disease, diabetes or asthma. Every year in the U.S., seasonal flu causes thousands of hospital admissions and deaths. The best way to help prevent flu is by getting a flu vaccine.

The Massachusetts Department of Public Health recommends influenza vaccine for all people 6 months of age and older. Vaccination is especially important for people at higher risk of severe influenza and their close contacts, including health care personnel and close contacts of children younger than 6 months.

Seasonal influenza vaccine can prevent seasonal influenza. The viruses that cause influenza change often. Because of this, influenza vaccine is updated each year by replacing at least one of the vaccine viruses with a newer one. Vaccine viruses included in the 2018-19 U.S. trivalent influenza vaccines will be an A/Michigan/45/2015 (H1N1)pdm09–like virus, an A/Singapore/INFIMH-16-0019/2016 (H3N2)-like virus and a B/Colorado/06/2017–like virus (Victoria lineage). Quadrivalent influenza vaccines will contain these three viruses and an additional influenza B vaccine virus, a

B/Phuket/3073/2013–like virus (Yamagata lineage).

Pneumococcal pneumonia is the most common serious complication of the flu. Every year thousands of people need hospital treatment and thousands of people die because of pneumococcal disease. Pneumococcal infection is the cause of more than one-third of pneumonia in adults. It is also the leading cause of pneumonia, blood infection and ear infection in children. Approximately one-half of these deaths potentially could be prevented through the use of vaccine. Pneumococcal vaccine is a safe and effective means of reducing illness. People are encouraged to contact their primary care providers to see if a pneumococcal vaccine is indicated.

There are things that one can do to protect oneself in conjunction with getting the flu vaccine.

• Avoid close contact with people who are sick. When you are sick, keep your distance from others to protect them from getting sick too.

• Stay home from work, school and errands when you are sick. You will help prevent others from catching your illness. CDC recommends staying home for at least 24 hours after your fever is gone.,

• Cover your mouth and nose with a tissue when coughing or sneezing. It may prevent those around you from getting sick.

• Clean your hands. Washing your hands often will help protect you from germs.

• Avoid touching your eyes, nose or mouth. Germs are often spread when a person touches something that is contaminated with germs and then touches his or her eyes, nose or mouth.

The Needham Public Health Department will offer subsequent seasonal influenza vaccine clinics. For questions, call the Needham Public Health Department at 781-455-7940, ext. 217, or go to **www.needhamma.gov/health**

LEGAL NOTICE

TOWN OF NEEDHAM - NOTICE OF PUBLIC HEARING

Friday, September 14, 2018, 7:00 AM – 9:00 AM
Hillside Conference Room, Rosemary Recreation Complex
178 Rosemary St, Needham MA 02494

The purpose of this Public Hearing is to: Revise Article 1, Regulation Affecting Smoking and the Sale and Distribution of Tobacco Products in Needham. The proposed amendment to the regulation is to add the workplace definition to the regulation. The regulation shall be considered in Needham in the interest of, and for the preservation of, the public health. This summary shall serve as notice to all.

Comments will be accepted at the public hearing, and will also be accepted through Friday, September 7th in writing via electronic or postal mail. Please send comments to healthdepartment@needhamma.gov or to Public Health Division, 178 Rosemary St, Needham, MA 02494. A copy of the regulation is available for interested parties to review on the Public Health Department's website at www.needham.gov/health.

Weekly 9/6/18

TOBACCO

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AD#13720531
Needham Times 8/30, 9/6/18

Needham offering Safety at Home Program

weekly 9/6/18

The Town of Needham Department of Health and Human Services is offering a new program, the Safety at Home Program, to help Needham residents ages 60 and older continue to live independently in their homes.

One in four older adults falls every year in the US. In Massachusetts, falls led to nearly 50,000 emergency department visits and over 22,000 hospitalizations in 2014. With Needham's new program, funded by the MetroWest Health Foundation, the Town hopes to prevent falls among its residents.

Participants in the Safety at Home Program will receive recommendations to make their homes safer and strategies to reduce their risk of falling. Participants will be eligible for:

- A free home safety assessment by a Town Social Worker or Public Health Nurse
- Connections to local resources
- Free home goods to improve safety
- Chance to enter a $50 gift card raffle

In honor of National Falls Prevention Awareness Day in September, the Town will be holding an event to launch the Safety at Home Program on September 6 at 1 p.m. at the Center at the Heights (300 Hillside Ave). An expert in fall prevention will speak and several community partners will share resources. This free event will include lunch.

Interested individuals can call the Center at the Heights at (781-455-7555) or email rgreenberg@needhamma.gov to register for the event or request a home assessment.

The Town wants all Needham residents to be able to live, work, and socialize without falling or a fear of falling.