

## Cardiovascular Consequences of Secondhand Tobacco Smoke Exposure in Youth

### 2016 Scientific Statement from the American Heart Association

David White, PhD  
Ward Family Heart Center  
Children's Mercy Hospital




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## Terms and Definitions

- SHS – Secondhand Smoke
- Cotinine – a metabolite of nicotine found in biological fluids, is a commonly used marker of tobacco smoke exposure.<sup>34</sup>
- NHANES – National Health and Nutrition Examination Survey
- CVD – Cardiovascular disease



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## Outline

- Prevalence
- Tobacco Smoke in the Home
- Cardiovascular Dysfunction
- Cardiometabolic Consequences of Smoke exposure
- Strategies to Reduce Exposure in the Home
- What we know about SHS in E-Cigarettes



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## Prevalence – Adults Who Smoke

- In 1964, ≈40% of adults in the US were smokers
  - 1/3 = women
- Decreased to an estimated 18% >45 million US adults still smoke (2015)
  - 500,000 die each year of tobacco smoke-related illnesses



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US Public Health Service, 1979;  
CDC, MMWR, 2011; Homa et al,  
MMWR, 2015

## Prevalence – Youth Exposed to Tobacco Smoke

- 24 million nonsmoking youth in the US are currently exposed to SHS
- Data from 2011 to 2012 NHANES
  - 41% of children
  - 34% of adolescents
    - Detectable serum cotinine levels (>0.05 ng/mL)



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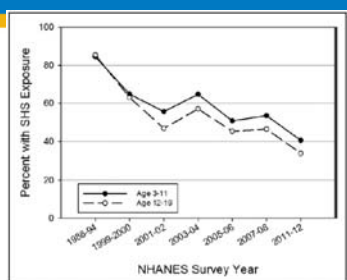
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Homa et al, MMWR, 2015

## Prevalence – Youth Exposed to Tobacco Smoke

- Exposure to SHS is decreasing!
  - Sample: non-smoking middle school and high school aged adolescents who self-reported exposure to SHS
    - Declined 59% to 34% between 2000 and 2009

## Prevalence – Youth Exposed to Tobacco Smoke



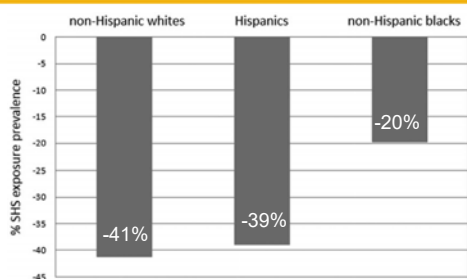
## Prevalence – Youth Exposed to Tobacco Smoke

- Despite these significant declines in exposure to SHS over the past 30 years ≈1 in 3 youth in the US is still exposed to SHS

## Prevalence – Race/Ethnicity

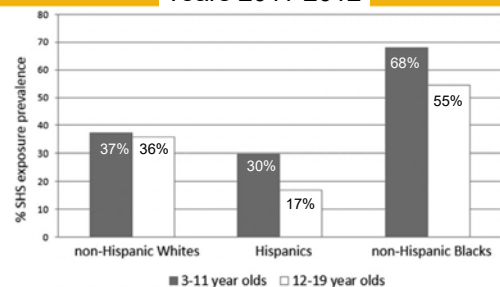
- Exposed to SHS in 2011-2012 (NHANES)
  - 31 million non-Hispanic white non-smokers
    - 7 million children and adolescents
  - 12 million non-Hispanic black non-smokers
    - 3 million children and adolescents
  - 6 million Hispanic non-smokers
    - 2 million children and adolescents

## Prevalence – Race/Ethnicity



## Prevalence – Race/Ethnicity

Years 2011-2012



## Prevalence – Race/Ethnicity

- For the same amount of exposure, cotinine levels are higher in younger children (compared with adults)
  - Higher exposure from faster respiratory rates
  - Inadequate cotinine metabolism

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## Prevalence – Socioeconomic Status

- NHANES data from 2011 to 2012
  - Poverty
    - Below the poverty level = 43% exposed
    - Above the poverty level = 21% exposed
  - Education
    - Grade 11 or less education = 28% exposure
    - College or graduate diploma = 12% exposure

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## Prevalence – Economic Impact

- Tobacco smoking related economic costs in the US exceed \$289 billion per year
  - 2009-2012 SHS exposure = \$5.6 billion in lost productivity

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## Prevalence – Economic Impact

- Children living with at least 1 smoker
  - Increased emergency department expenditures
  - Increased inpatient use
- Additional costs associated in pregnant women smoking tobacco or being exposed to SHS

≈\$2 billion per year

Levy et al., BMC Health Serv Res, 2011  
Hill et al., Tob Control, 2008  
CDC, MMWR, 1997

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## Missouri Specific

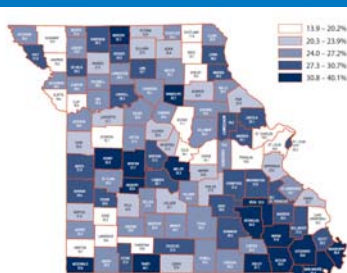


Fig-1  
Smoking Prevalence (18 Years and Older)

Missouri Foundation for Health, 2007  
Missouri County Level Study of Adult Tobacco Use and Related Chronic Conditions and Practices, Executive Summary

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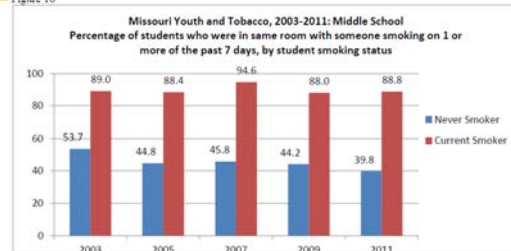
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## Missouri Specific

Figure 16



Missouri Department of Health and Senior Services, Missouri Youth and Tobacco, 2003-2013; A decade of progress in prevention

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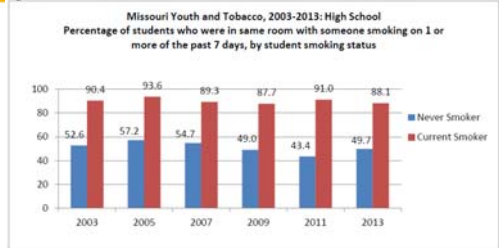
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## Missouri Specific

Figure 17



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Missouri Department of Health and Senior  
Services, Missouri Youth and Tobacco, 2003-  
2013; A decade of progress in prevention

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## Kansas Specific

- 8.8% of Kansas adults were exposed to SHS at home in the past week
- 16.5% of Kansas adults live in households where smoking is allowed

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Kansas Department of Health and Environment,  
Secondhand Smoke Exposure and Smoke-free  
Household and Vehicle Rules among Kansas High  
school Student, Kansas Health Statistics Report, 2013

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## Kansas Specific

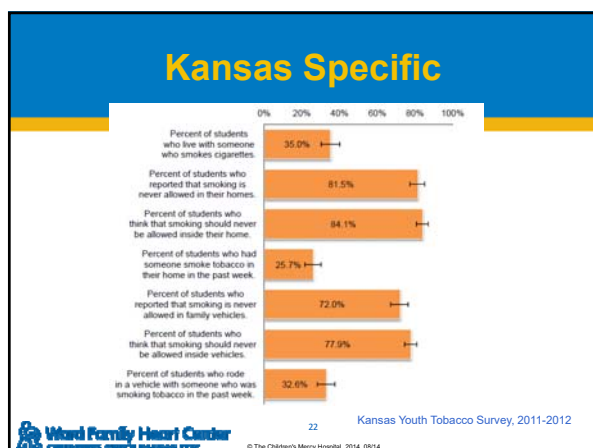
- 1 in 4 (25.6%) Kansas adults who live in multi-unit housing were exposed to SHS from inside or outside their residential building within the past year
- 78% of adults think smoking should never be allowed indoors in restaurants

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Kansas Department of Health and Environment,  
Secondhand Smoke Exposure and Smoke-free  
Household and Vehicle Rules among Kansas High  
school Student, Kansas Health Statistics Report, 2013

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### Outline

- Prevalence
- Tobacco Smoke in the Home
- Cardiovascular Dysfunction
- Other Health Consequences of Smoke Exposure
- Strategies to Reduce Exposure in the Home
- What we know about SHS in E-Cigarettes

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### SHS in the Home

- >98% of children and adolescents living with someone who smokes at home have detectable SHS exposure
  - Not much different than 1988

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CDC, MMWR, 2010; Mannino et al., Chest, 2001  
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## SHS in the Home

- Why such a high prevalence?
- Children have less control over home and social environments, leading to an increased likelihood of involuntary, confined exposure to SHS

## SHS in the Home

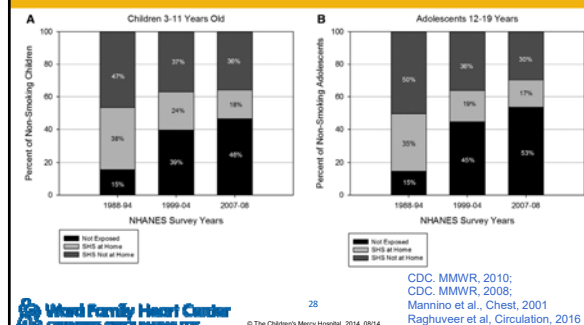
- Youth living with someone who smokes inside the home

Time point	Children (age 3-11)	Adolescents (age 12-17)
1994-1998	38%	35%
1999-2004	24%	20%
2007-2008	18%	17%

## SHS in the Home

- Prevalence of SHS exposure in the home
  - Rent housing = 37%
  - Owned housing = 19%
- Home smoking bans use is lower
  - Low income
  - Single parent
  - Lower educational attainment

## SHS in the Home



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## Chemical Composition of SHS

- Effects of tobacco smoke depend on
  - Direct smoking or SHS
  - Distance of those exposed from source
  - Length of time from the constituents entering the environment to exposure
    - environmental SHS aging
  - Whether the SHS is mainstream or side stream smoke



## Chemical Composition of SHS

- The toxicity of some constituents in side stream smoke increases over time
  - Ambient environmental reactions in which certain compounds deposit onto surfaces
    - Third hand smoke
  - Other gas constituents remain suspended in air

## Chemical Composition of SHS and Cardiovascular Disease

- Acute exposure
  - Endothelial function
  - Vasoconstriction
  - Heart rhythm
  - Platelet function
  - Autonomic function
  - Inflammation
- Subacute exposure
  - Dyslipidemia
  - Reduced insulin sensitivity
  - Inflammation via oxidative stress
  - Endothelial dysfunction
  - Thrombosis

## Chemical Composition of SHS and Cardiovascular Disease

- Cardiovascular effects of specific chemicals
  - **Nicotine:** hemodynamic alterations
  - **Acrolein:** oxidation, inflammation, atherogenesis, hypertension, and arrhythmia
  - **Crotonaldehyde:** plaque instability and thrombosis
  - **Cadmium:** inflammation
  - **Lead:** hypertension
  - **Particulate matter:** arrhythmias and inflammation

## Chemical Composition of SHS and Cardiovascular Disease

- Exposure to carbon monoxide and metals is minimal through SHS
- Nicotine exposures are also quite low
  - Nicotine dissipates rapidly from SHS

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## Quick Review of Vascular Physiology – Endothelium

- Vascular endothelium plays a central role in cardiovascular homeostasis
  - Arterial tone
  - Cell proliferation
  - Platelet interaction
  - Thrombogenesis
  - Leukocyte adhesion
  - Regulates many other things
- A healthy endothelium maintains a normal dilator state and anti-thrombotic surface, while regulating processes are thought to play a key role in early atherogenesis

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## Methods to Assess Vascular Health

- Arterial flow-mediated dilatation (FMD)
  - Measures vasodilator response to shear stress
  - Endothelial release of nitric oxide
  - Platelet aggregation
  - Inhibition of leukocyte adhesion
  - Smooth muscle cell proliferation
- Has been shown to predict cardiovascular events

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## Quick Review of Vascular Physiology – Arterial Function

- Arterial function
  - The transmission of blood flow to downstream tissue capillary beds with minimal energy loss
  - Regulation of blood flow to tissue capillary beds
- Determined by the structure and function of large conduit and small resistance arteries

## Methods to Assess Vascular Health

- Carotid artery intima-media thickness (CIMT)
  - CIMT captures the effect of accumulated cardiovascular risk factors to the arterial wall
    - 1-mm increase in CIMT measurement in adults, the hazard ratio for CVD increases by 2.5
- Other methods
  - Carotid-femoral pulse-wave velocity

## SHS and Cardiovascular Dysfunction – Human Studies

- The acute effects of SHS on the coronary circulation in healthy young adults.



## SHS and Cardiovascular Dysfunction – Human Studies

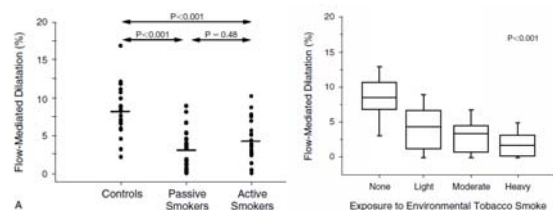
- Celermajer et al., NEJM, 1996
- n=78 (age 15–30 years)
  - 26 active smokers
  - 26 who had never smoked but had been exposed to SHS for at least 1 hour daily for  $\geq 3$  years
  - 26 control subjects who were not SHS exposed or actively smoking

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## SHS and Cardiovascular Dysfunction – Human Studies



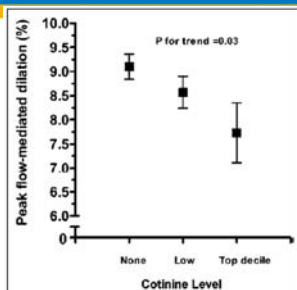
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Celermajer et al., NEJM, 1996

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## SHS and Cardiovascular Dysfunction – Human Studies

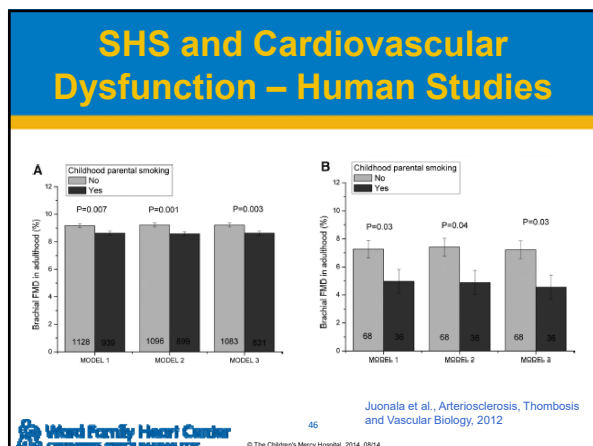


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Kallio et al., Circulation, 2007

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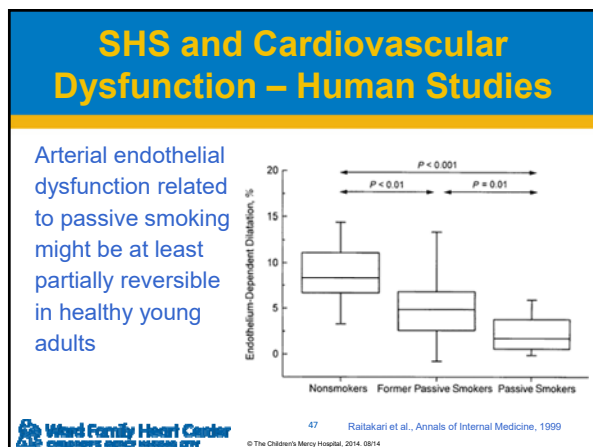
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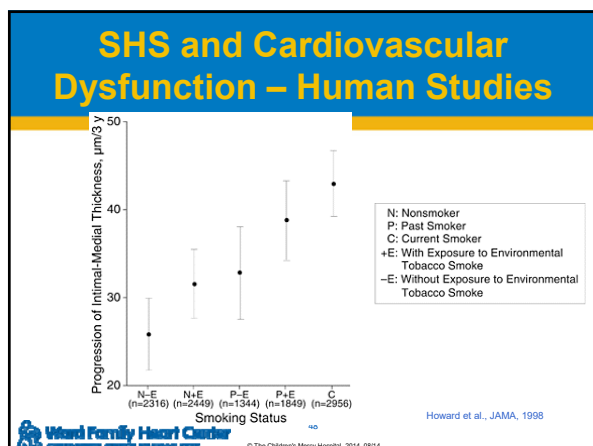
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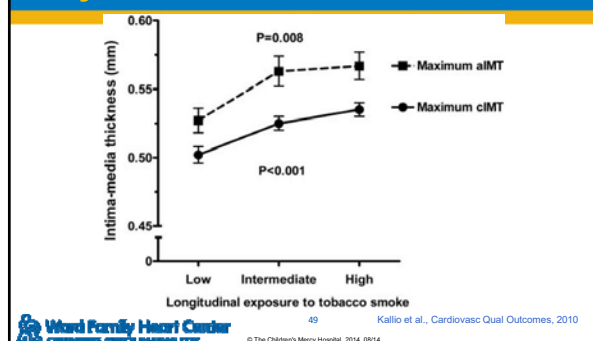
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## SHS and Cardiovascular Dysfunction – Human Studies



## SHS and Cardiovascular Dysfunction – Human Studies

- The effect of short-term SHS exposure on muscle sympathetic nerve activity
  - One smoke inhalation session increased resting muscle sympathetic nerve activity by ≈20%
- This finding could in part underscore the association between SHS exposure and blood pressure in children

50 Hausberg et al., Circulation, 1997  
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## SHS and Cardiovascular Dysfunction – Human Studies

- Exposure to SHS has significant effects on endothelial and arterial function for many years after exposure
  - Damage can be equivalent or worse than active smoking
  - Some reversibility

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## SHS and Arrhythmia

- Schuetz and Eiden, Infant Behav Dev, 2006
  - Neonates with in utero SHS exposure had higher heart rates and lower heart rate variation with breathing than those in the non-exposed group
- Dixit et al., Heart Rhythm, 2016
  - SHS exposure in utero and during childhood was associated with atrial fibrillation later in life

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## SHS and Arrhythmia

- SHS exposure is associated with the release of epinephrine and norepinephrine
  - similar to direct cigarette smoking
- Smoke exposure has a powerful sympathetic excitatory effect influencing sympathetic drive to blood vessels, skin, and the heart

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## SHS and SIDS

- The risk of SIDS is greater in infants if they are exposed in utero and/or in the postnatal period
- The risk of SIDS increases with increasing dose of SHS exposure

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## SHS and Cardiometabolic Disease – Obesity

- The overall pattern appears to be one of lower weight at birth and larger postnatal weight gain
  - Longitudinal Healthy Start Study

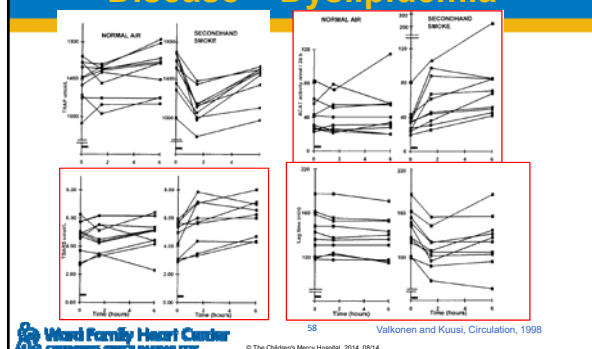
## SHS and Cardiometabolic Disease – Obesity

- The National Institute of Child Health and Human Development Study

**Table 4** The joint effect of prenatal smoking and SHS exposure on the development of adolescent obesity using generalised estimating equations (n = 9321)

Exposure variables		No. of Participants	Adolescents who developed obesity			
			Percentage (n)	OR (95% CI)		
Prenatal smoking	SHS exposure			Model 1	Model 2	Model 3
<b>Overall</b>						
No	No	576 (61.80)	20.5 (118)	1.00	1.00	1.00
Yes	No	73 (7.85)	21.9 (16)	1.25 (0.68–2.29)	1.04 (0.53–2.03)	1.07 (0.55–2.07)
No	Yes	148 (15.92)	27.0 (40)	<b>1.55 (1.02–2.35)*</b>	1.20 (0.74–1.95)	1.15 (0.70–1.88)
Yes	Yes	135 (14.53)	31.1 (42)	<b>2.02 (1.33–3.07)**</b>	<b>2.10 (1.24–3.56)**</b>	<b>2.28 (1.33–3.90)**</b>

## SHS and Cardiometabolic Disease – Dyslipidemia




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## SHS and Academic Performance

- Children exposed to SHS have higher rates of adverse behavioral and cognitive effects, including ADHD
- Levy et al. Pediatrics, 2011
  - Children living with adults who smoke at home are absent from school 1.5 more days a year than children living with nonsmokers.

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## SHS and Academic Performance

- Max et al., School Health, 2014
  - SHS costs to the education system may be 4 times higher than the annual healthcare cost attributable to ADHD
  - Caregivers' time tending to children absent from school is estimated to cost \$227 million each year.

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## SHS Reduction Strategies

- Intervention strategies fall into 2 broad groups
  - Directly minimize SHS exposure to children
  - Indirectly minimize SHS exposure by assisting parents/caretakers to quit or reduce smoking
- The majority of studies have targeted parents rather than non-parental caregivers.

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## SHS Reduction Strategies

- Interventions that directly minimize SHS exposure to children
  - Counseling and materials for parents
    - Not to allow smoking in the home, car, and around their children
    - Remove the child from rooms in the home or other locations when smoking is taking place

### Hygienic smoking

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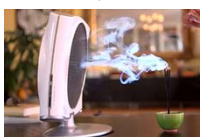
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## SHS Reduction Strategies

- Interventions that directly minimize SHS exposure to children
  - Use of air cleaners
  - Biochemical feedback (cotinine measurement)



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## SHS Reduction Strategies

Are these interventions successful?

Rosen et al, Pediatrics, 2014

- Parent reported exposure (n=17)
- Cotinine (n=13)

Parent reported = 'small benefits'

Objective measures (cotinine) = no effect

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## SHS Reduction Strategies

Are these interventions successful?

Baxi et al, Cochran Database Syst Rev, 2014

n=57 studies

Only 14 studies showed significant intervention treatment effect

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## SHS Reduction Strategies

### In home and/or in car smoking bans

Characteristics	Prevalence of SHS exposure Percent (SE)			
	Overall	Home only	Car only	Both
Total	40 (2.0)	6 (0.8)	12 (3.0)	22 (5.4)
Gender				
Female	40 (2.4)	4 (1.0)	12 (3.3)	23 (2.2)
Male	39 (2.1)	7 (0.9)	13 (1.4)	20 (1.4)
Race/ethnicity				
Caucasian	40 (2.9)	6 (1.0)	12 (1.4)	23 (2.3)
African American	40 (2.3)	7 (1.1)	12 (1.7)	21 (2.0)
Other	29 (4.2)	3 (0.2)	14 (4.4)	12 (4.4)
Age (in years)				
11-12	39 (4.4)	5 (0.4)	13 (2.1)	21 (2.9)
13-14	41 (2.4)	5 (0.1)	12 (1.8)	24 (2.1)
15-16	40 (2.3)	6 (1.3)	11 (1.3)	22 (2.2)
>17	37 (6.1)	9 (2.4)	12 (2.3)	16 (4.9)
Grade				
6	44 (5.0)	4 (0.3)	14 (2.3)	25 (5.0)
7-8	38 (2.4)	5 (0.2)	10 (1.4)	23 (1.4)
9-10	39 (2.3)	5 (0.2)	12 (1.5)	22 (2.3)
11-12	37 (5.1)	9 (2.4)	12 (2.0)	16 (4.1)
Lives with a smoker				
Yes	73 (1.8)	11 (0.9)	12 (1.4)	51 (2.4)
No	21 (1.8)	3 (0.7)	12 (1.3)	5 (0.7)

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Cartmell et al, Public Health Rep, 2011

## SHS Reduction Strategies

Characteristics	N	Prevalence of reported SHS exposure				Prevalence difference			
		Rules (partial or strict)			No rules Percent (SE)	B-A	P-value <sup>a</sup>	C-A	P-value <sup>b</sup>
		Overall	A Home and car b=2000	B Home or car b=154					
Total	602	73 (1.8)	55 (3.4)	85 (2.3)	91 (2.0)	30	<0.0001	36	<0.0001
Gender									
Female	329	75 (2.3)	56 (4.8)	85 (4.4)	92 (2.4)	29	0.0009	37	<0.0001
Male	273	71 (2.1)	53 (3.1)	84 (4.4)	88 (3.4)	33	0.0001	35	<0.0001
Race/ethnicity									
Caucasian	338	80 (2.3)	62 (3.7)	92 (3.2)	92 (2.1)	30	<0.0001	30	<0.0001
African American	230	66 (2.4)	47 (4.2)	75 (5.4)	91 (3.0)	28	0.015	44	<0.0001
Other	34	53 (8.7)	43 (11.3)	91 (7.4)	52 (22.3)	48	0.0001	9	0.72
Age (in years)									
11-12	128	70 (4.7)	54 (8.3)	66 (9.4)	95 (3.9)	10	0.42	39	0.0002
13-14	221	75 (4.2)	52 (4.4)	91 (3.2)	88 (4.2)	39	<0.0001	36	<0.0001
15-16	186	74 (2.3)	53 (4.7)	89 (2.3)	97 (1.9)	36	<0.0001	44	<0.0001
>17	87	75 (6.0)	61 (9.8)	94 (5.3)	81 (8.5)	33	0.005	20	0.11
Grade									
6	124	77 (4.9)	62 (8.3)	82 (8.7)	94 (3.8)	20	0.024	31	0.0012
7-8	227	72 (3.0)	53 (4.5)	81 (4.5)	89 (4.4)	29	0.0037	34	0.0002
9-10	168	71 (3.4)	48 (4.7)	93 (3.0)	93 (3.1)	45	<0.0001	45	<0.0001
11-12	83	76 (5.1)	63 (7.9)	86 (4.7)	87 (7.8)	23	0.01	24	0.04

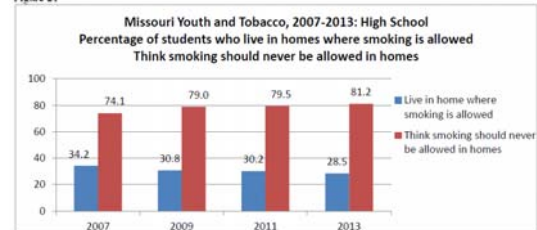
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Cartmell et al, Public Health Rep, 2011

## SHS Reduction Strategies

Figure 21




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Missouri Department of Health and Senior Services, Missouri Youth and Tobacco, 2003-2013: A decade of progress in prevention

## SHS Reduction Strategies

- 67% of Kansas adults who live in multi-unit dwellings favor rules prohibiting smoking in shared common areas



Kansas Department of Health and Environment, Secondhand Smoke Exposure and Smoke-free Household and Vehicle Rules among Kansas High school Student, Kansas Health Statistics Report, 2013



70  
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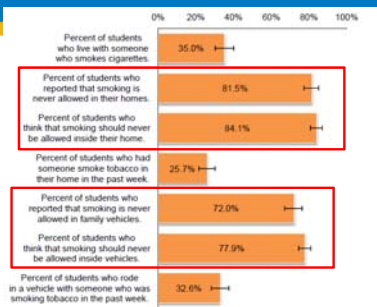
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## SHS Reduction Strategies



Strategy	Percent of students
Percent of students who live with someone who smokes cigarettes	35.0%
Percent of students who reported that smoking is never allowed in their homes	81.5%
Percent of students who think that smoking should never be allowed inside their home	84.1%
Percent of students who had someone smoke tobacco in their home in the past week	25.7%
Percent of students who reported that smoking is never allowed in family vehicles	72.0%
Percent of students who think that smoking should never be allowed inside vehicles	77.9%
Percent of students who rode in a vehicle with someone who was smoking tobacco in the past week	32.6%



71  
Kansas Youth Tobacco Survey, 2011-2012  
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## SHS Reduction Strategies – CEASE Program



**CEASE**  
[www.ceasetobacco.org](http://www.ceasetobacco.org)



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