SLEEP MEDICINE

HARVARD MEDICAL SCHOOL

The Harvard Medical School Division of Sleep Medicine is pleased to present

# The Price of Fatigue:

## The surprising economic costs of unmanaged sleep apnea

as an educational resource to increase awareness among the general public and with policy makers about the significance of this public health problem.

McKinsey & Company contributed to the fact base and analysis in this report. This project was funded by Sleep For America.

December 2010

# Sources for this meta-analysis: interviews, academic papers and market research on sleep apnea and co-morbidities

NOT EXHAUSTIVE

**Primary research: 10+ Interviews with MDs and leaders from private / public sleep centers and insurance providers**

- Pulmonologist & Medical Director of a large Sleep Center
- Assoc. Prof. & Director of Sleep Medicine program at large Mid-Western University
- Senior Medical Director responsible for durable medical equipment at a large private insurer
- Medical Director for care mgmt at a large private insurer
- Director of Respiratory Care Sleep Lab at a major hospital
- Assistant Prof. and Director Sleep Medicine Fellowship of a large East Coast University
- CEO of large West Coast sleep center and DME
- McKinsey & Company health economics experts
- McKinsey & Company experts on DMEs
- MDs within McKinsey with experience diagnosing and treating OSA (pulmonologists, internal medicine)

**Secondary research: University, government, and industry-sponsored studies and market reports**


- AlGhanim, N et al. Lung (2008)
- American Heart Association
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- Australian Bureau of Statistics (2000)
- Colton, H; Altevogt, B. Institute of Medicine (2006)
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- US Bureau of Labor Statistics (2009)
- Young, T et al. Sleep 2008;31(8):1071-1078
- Young, T et al. Arch Intern Med. 2002;162:893-900
- Young, T et al. Sleep, 1997, 20(9):705-706
- Young, T et al. N Engl J Med 1993 (328) 1230-5
- Jefferies & Co, 2008 ResMed initiating coverage report


Note: McKinsey & Company has contributed to the fact base and analysis in this report

# Executive Summary

- Like all meta-analyses, this work relies on the quality of existing data - we focused on areas where the link between the disease and the costs incurred are the strongest. This includes:
  - Moderate – severe OSA and OSAS (AHI ≥ 15 or OSA Syndrome)
  - Does not include mild OSA and costs that are difficult to size (e.g., presenteeism, impact on family life, marriage, etc and other societal costs)
- We estimate the annual economic cost of moderate - severe OSA in the United States to be $65 - $165B, which are greater than asthma, heart failure, stroke and hypertensive disease ($20B to $80B)
- Yet, OSA attracts limited public attention (e.g., OSA related traffic accidents cost ~$35B versus well-known public safety threats such as drunk driving ($60B) and not wearing seatbelts ($150B))
- Awareness, diagnosis, and treatment of OSA are limited by the economics and nature of the condition
  - OSA costs are highly fragmented and touch many disconnected stakeholders
  - Current technology, while effective at treating the disease, is cumbersome and uncomfortable for many
  - Low patient compliance limits the cost effectiveness of treatment for payors
- Opportunities to reduce the costs of sleep apnea include:
  - More holistic research to understand the current and projected costs of the disease (e.g., prevalence, co-morbidities)
  - Building a cohesive community of stakeholders (e.g., physicians, patients, employers, public safety officials, etc) to drive awareness
  - Improving the patient experience and comfort in treatment to drive adoption
  - Convincing payors and employers of the long-term economic benefits of screening and treatment

# Total economic costs of moderate-severe OSA

| **Estimated total economic cost of moderate-severe OSA** | **~$65-165B+ annually in the U.S.** |
|---|---|
| ▪ Diagnosis and treatment of moderate-severe OSA costs: | ▪ $2 - $10B |
| ▪ Hidden healthcare costs from moderate-severe OSA driven by:<br>– Co-morbidities (e.g., CVD, renal disease, diabetes and depression)<br>– Medical costs of accidents | ▪ $45 - $80B |
| ▪ OSAS-related traffic accident (*excluding medical costs captured above):* | ▪ $10 - $40B |
| ▪ OSAS-associated workplace accidents *(excluding traffic accidents and medical costs captured above):* | ▪ $5 - $20B |
| ▪ OSAS-related lost productivity costs driven by absenteeism*: | ▪ $5 - $15B |
| ▪ Additional societal impact (e.g., increased divorce rates, loss of intimacy): | ▪ Not sized |

*Additional presenteeism costs not directly estimated

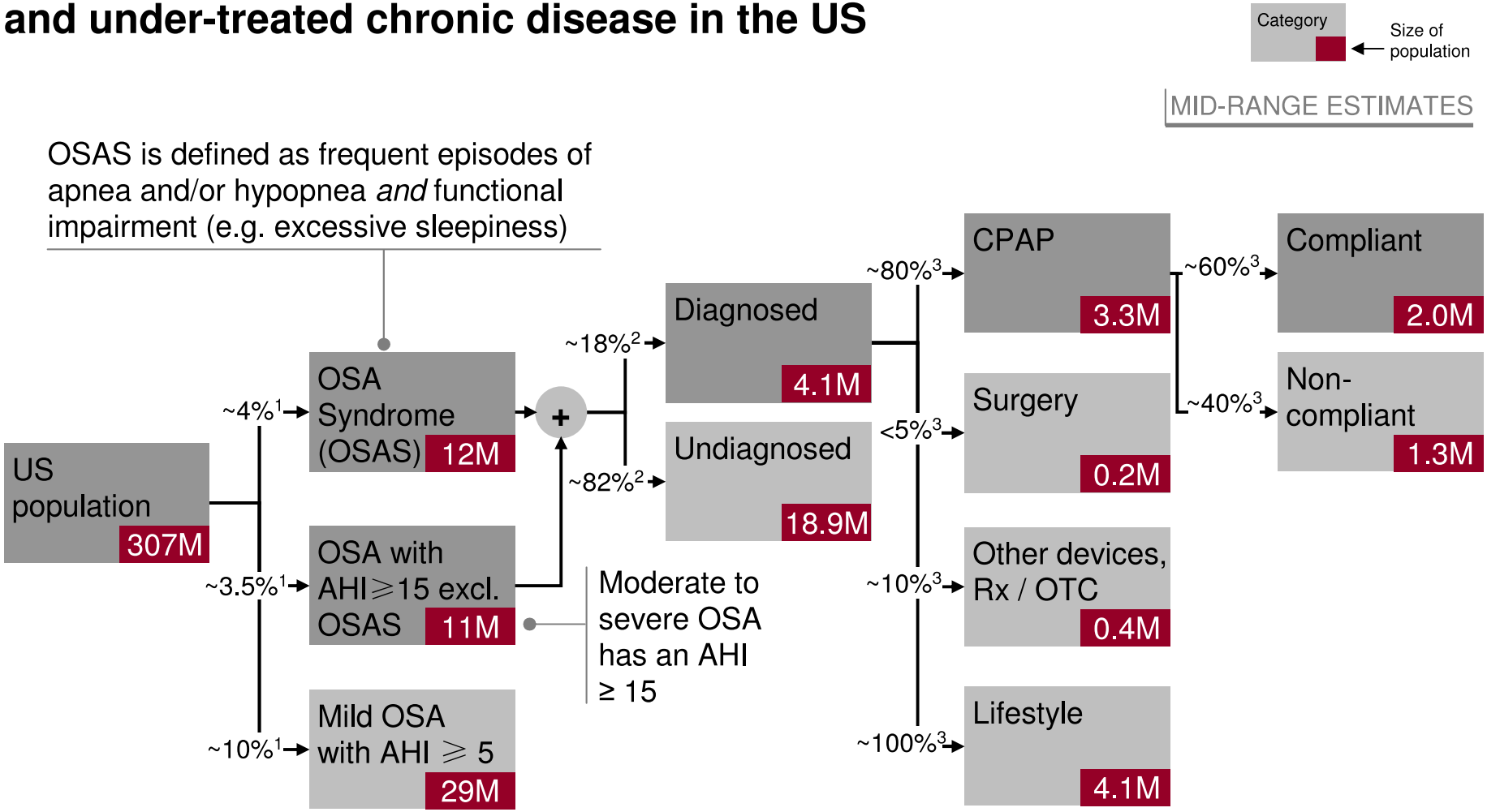
SOURCE: Young T, Sleep, 1997, 20(9):705-706; Young T N Engl J Med 1993 (328) 1230-5; Engleman H, Sleep Med Rev, 2003, 7(1):81-99

## Contents

**Economic cost of OSAS**

Cost estimation approach

# Obstructive Sleep Apnea is a significant, yet under-diagnosed and under-treated chronic disease in the US




1 OSAS prevalence: 3 - 5%; OSA prevalence with AHI ≥ 15: 6.5 - 8.5%; mild OSA prevalence 9 – 24% (assumed 17%)
2 OSAS diagnosis rates are estimated to be 15-20%
3 Estimate from expert discussions and literature research. Lifestyle changes are suggested for almost all patients
NOTE: The severity of OSA is often characterized by the AHI; however, there is no strong correlation between AHI and incidence of daytime functional impairment

SOURCE: Young T, Sleep, 1997, 20(9):705-706; Young T N Engl J Med 1993 (328) 1230-5; Engleman H, Sleep Med Rev, 2003, 7(1):81-99

# US OSAS prevalence is estimated at 3-5%; prevalence of moderate-severe OSA is estimated at 6.5-8.5%

ESTIMATES

**Public health costs**

- Clear link established between moderate-severe OSA (AHI ≥ 15) and co-morbitidies (e.g., treating OSA reduces CVD outcomes)
- We assume **diagnosis / treatment and hidden healthcare costs apply to all people with moderate-severe OSA** (which includes those with OSAS)

**Public safety costs**

- Limited published data on extent of self-reported sleepiness under-estimation[2]
- We have chosen to estimate **non-healthcare costs for the population with people with OSAS only**

| | Age group | | | |
|---|---|---|---|---|
| | **< 30** | **30-60** | **60+** | **Wt. avg. by age** |
| **Prevalence of OSAS** Percent | 1.5-2.5[1] | 2.5-4.5[1] | 4.5-9.5[1] | **3-5** |
| **Prevalence of AHI ≥ 15** Percent | ~3-4[1] | ~5.5-7.5[1] | ~19-21[1] | **6.5-8.5** |
| **Population in age group** Percent | 41 | 42 | 17 | |

Applied to public safety cost calculations

Applied to public health costs calculations

1 Scaled to take into account prevalence growth drivers (obesity and age)
2 One traffic accidents study suggests ~20% of people underestimate their sleepiness

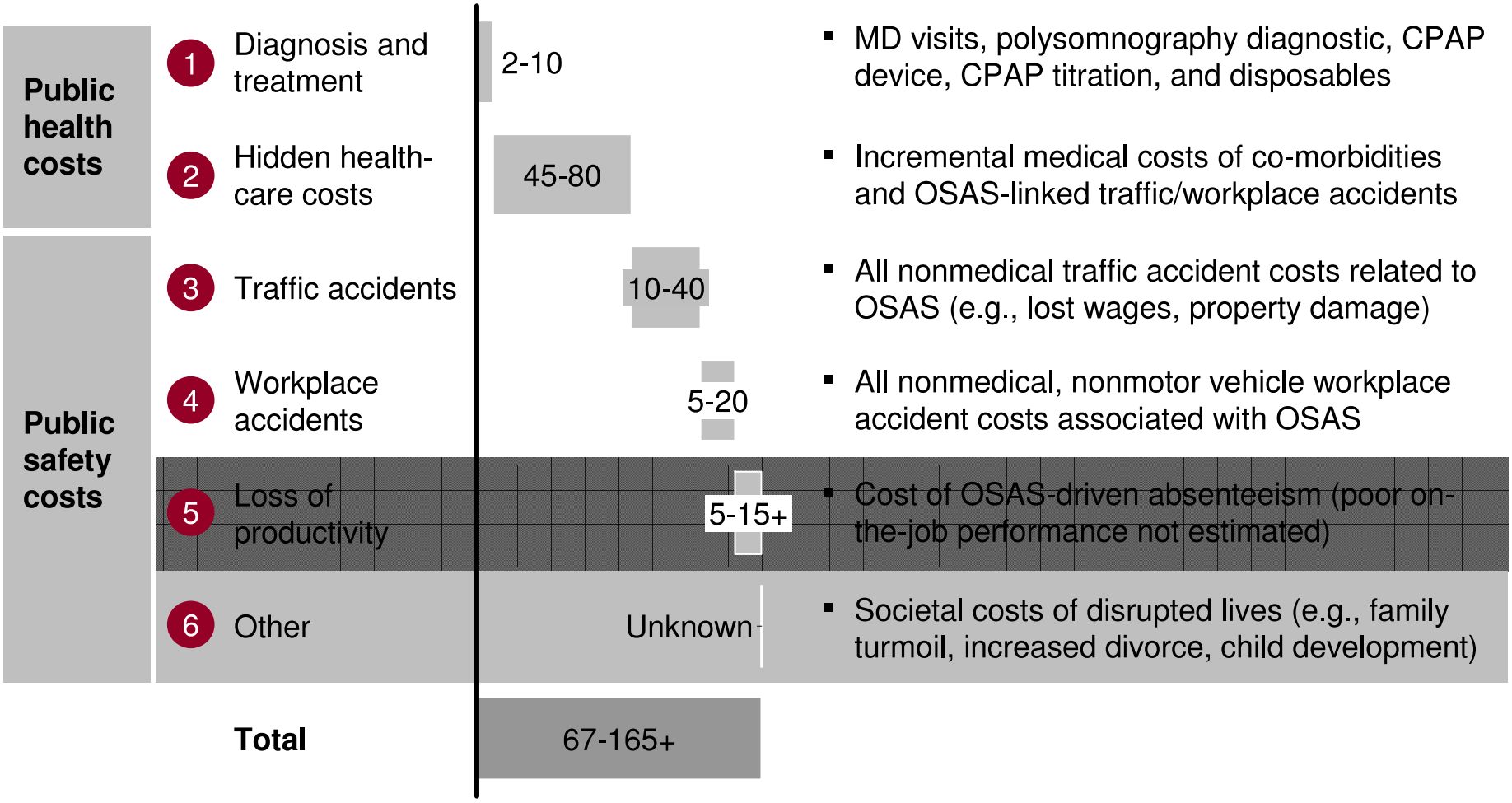
SOURCE: Rosen C, Pediatr Clin N Am 2004;51:153-167; Gislason T, Chest 1995;107:963-966; Kapur V, Respiratory Care 2010;55:1155-1167; Young T et al. Arch Intern Med. 2002;162:893-900; Young T et al. N Engl J Med 1993; 328:1230-1235

# Economic cost of unmanaged moderate-severe OSA in the US estimated between ~$65B and $165B

PRELIMINARY

Partially sized
Not sized

**Estimated annual economic cost of OSA/OSAS in the US**
$ Billions




SOURCE: Academic papers, expert interviews, market reports

# Difficult to estimate factors could significantly increase or decrease the economic costs of OSA

ROUGH ESTIMATES

| | Potential impact of key drivers | Max adjustment |
|---|---|---|
| **Mild OSA** | ▪ Public safety costs for OSAS applied to all moderate-severe OSA patients[1]<br>▪ Mild OSA is defined by an AHI between 5 and 15 and has a prevalence of ~8-11% in the US<br>▪ The public health and safety costs of mild OSA are poorly understood (e.g., link with CVD)<br>▪ The upper bound of the incremental costs of mild OSA could be $85-175B assuming:<br>– Public healthcare costs per person for moderate-severe OSA applied to all people with mild OSA | + **~$85-175B** |
| **Comorbidities** | ▪ Several co-morbidities have been associated with OSA including CVD, depression and renal failure<br>▪ However, OSA has only been causally linked in the literature with hypertension, and certain other CVDs<br>▪ As a result, it is possible that treating OSA would not remove all of the hidden healthcare costs<br>▪ There is a need for continued research in this area | – **~$45-80B[2]** |

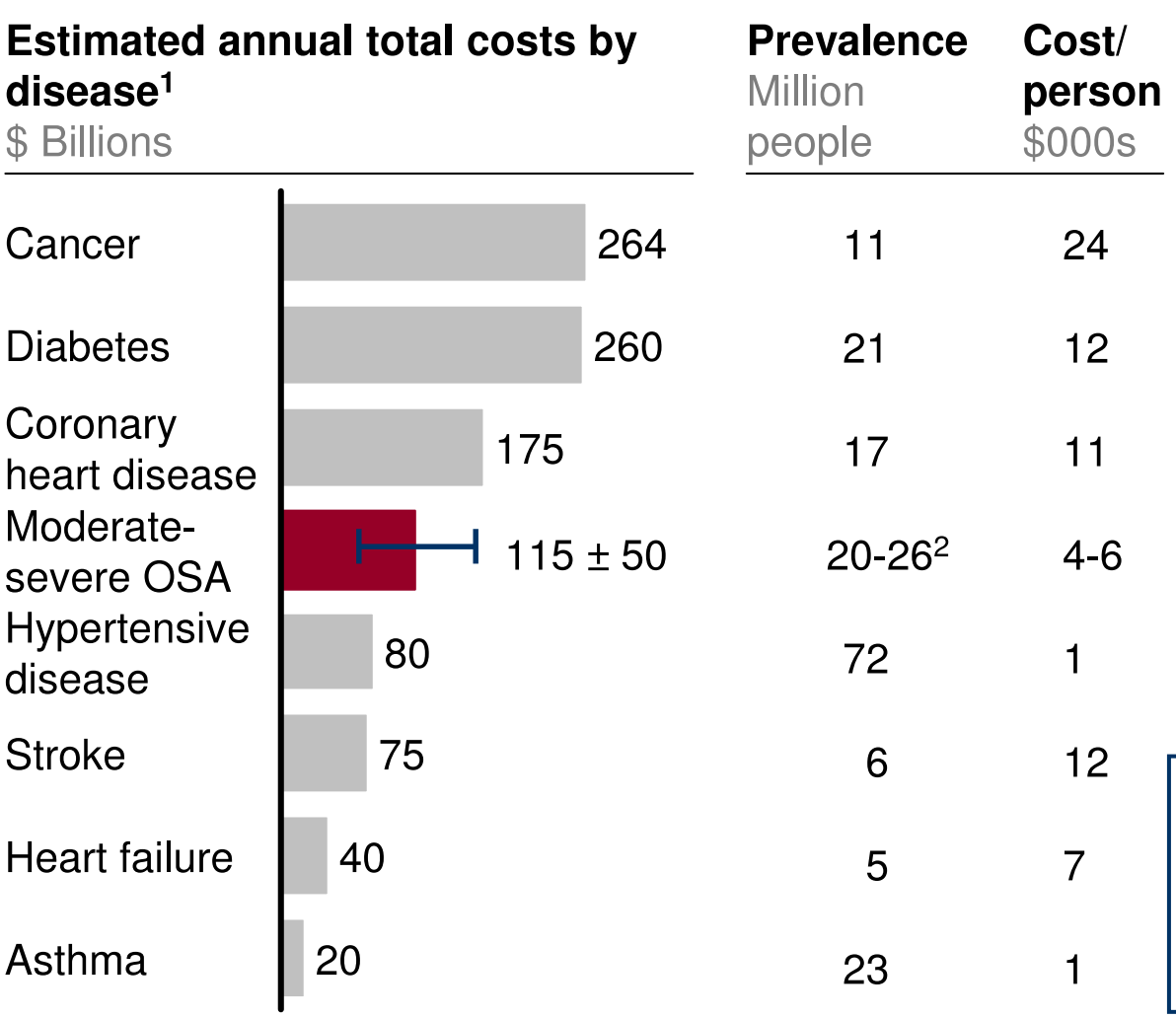
1 Moderate-severe OSA has a prevalence of 6.5 – 8.5% in the US

2 If co-morbidities are not reduced through OSA treatment the economic costs of OSA would be reduced by the hidden healthcare costs (these would be approximately $60-90B higher if mild OSA is included in the estimate.

# Moderate – severe OSA has significant economic cost relative to other diseases, yet requires a relatively inexpensive treatment approach

ESTIMATES

NOT EXHAUSTIVE




Co-morbidity costs of OSA are also counted in other disease estimates

1 Total cost estimation approach varies by disease in ways that cannot be easily compensated for (e.g., inclusion of mortality and/or morbidity costs). Estimates for diseases other than OSA largely included less costs.

2 Assumes prevalence of moderate – severe OSA is 6.5% - 8.5%

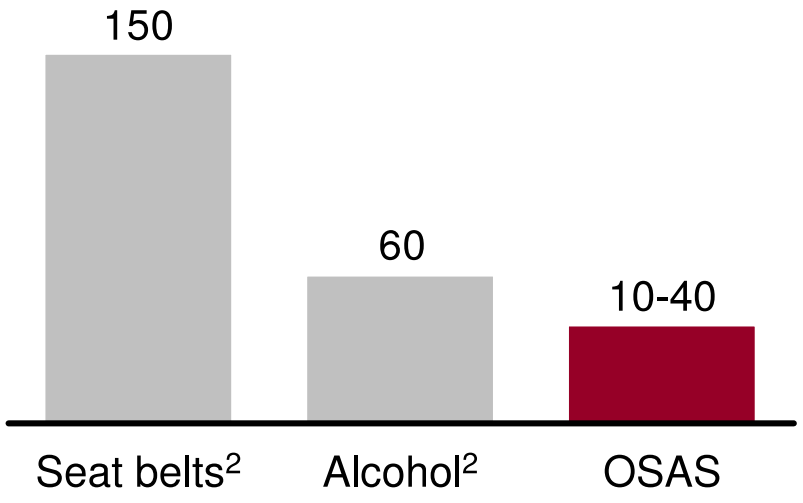
SOURCE: American Heart Association; American Diabetes Association; National Heart; Lung and Blood Institute, American Cancer Society

# OSAS is associated with a significant fraction of total traffic accident costs ("drowsy driving"), but awareness is low

ESTIMATES

## Despite the substantial traffic accident cost associated with OSAS …

Traffic accident cost[1], $ Billions, 2010




## … it attracts relatively little national attention

- No prevalent educational and advocacy efforts for OSAS, unlike drunk driving and seat belts
- Few, small nonprofits dedicated to OSAS awareness[2], compared to many, well-funded groups for drunk driving
- State advertising campaigns and associated law enforcement efforts for both seatbelts and drunk driving, but few programs for fatigue

1 These cost estimates are not mutually exclusive (e.g., seatbelt accident costs do not exclude alcohol related accidents)
2 Identified the proportion of 2008 injuries and deaths attributed to each cause and multiplied by 2010 total traffic accident costs
3 American Sleep Apnea Association and American Sleep Association

SOURCE: National Highway Traffic Safety Administration

# The economic costs of OSAS are fragmented, touching many independent stakeholders, which presents a barrier to awareness and treatment

NOT EXHAUSTIVE

**Economic stakeholders**

**Diagnosis and treatment**
- Primary-care physicians
- ENT specialists
- Sleep doctors
- Sleep centers
- Medical device (CPAP) manufacturers
- DMEs
- Healthcare insurers

**Hidden health-care costs**
- Co-morbidity specialists (e.g., cardiologists, endocrinologists, etc.)
- Hospitals and clinics
- Healthcare insurers

**Traffic accidents**
- Highway traffic safety administration
- Local / state emergency resources
- Automobile insurers

**Workplace accidents**
- Occupational medicine specialists
- Employers
- Lawyers

**Loss of productivity**
- Employers
- Employees

**The wide variety of disconnected stakeholders make it difficult for a champion to emerge to coordinate action to reduce the overall economic impact of OSAS**

# Assuming 100% effective treatment, low patient compliance would limit the cost effectiveness of treatment and support of some stakeholders

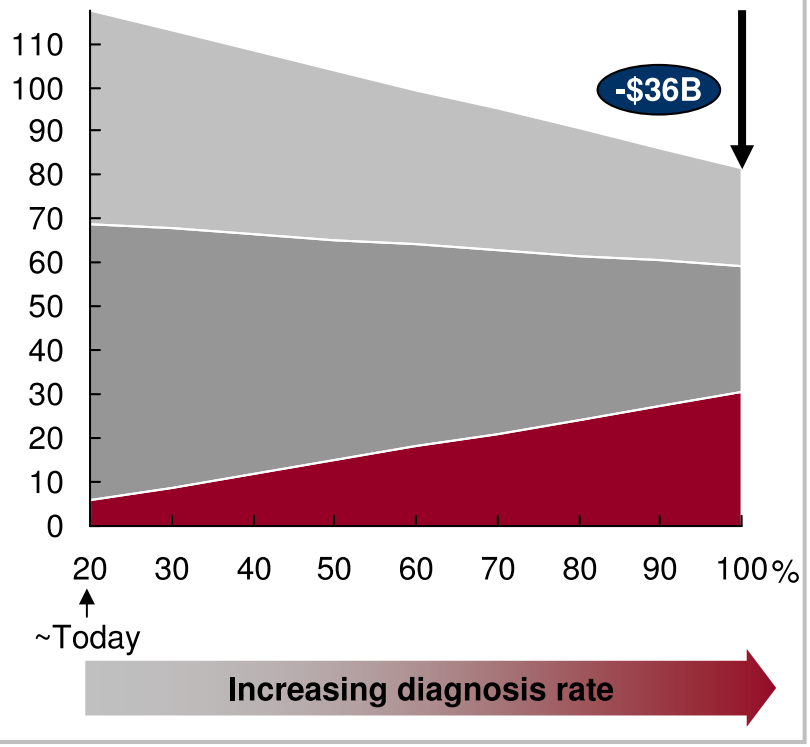
Nonhealthcare costs | Hidden healthcare costs | Diagnosis/treatment costs

ILLUSTRATIVE

## Assuming 100% effective treatment, increasing diagnosis would drive economic benefits …

**Max. cost impact of increased OSA diagnosis rate**

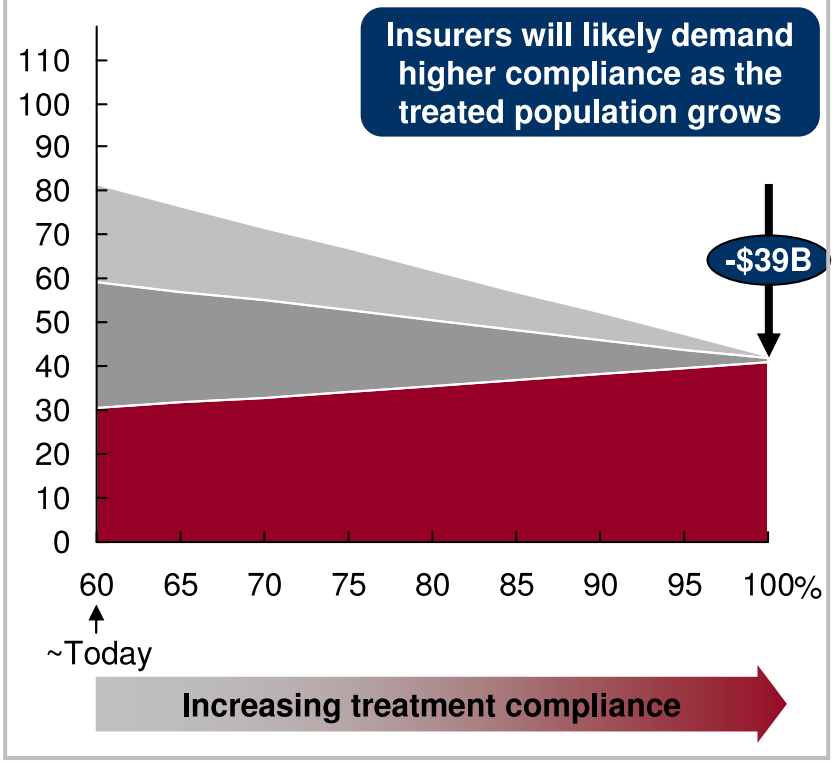
$ Billions – Average of min and max range




## … however, even with 100% diagnosis, compliance would remain a critical limiting factor

**Max. cost impact of increased OSA treatment compliance at 100% diagnosis rate**

$ Billions – Average of min and max range




Note: Assumes diagnosed and treated OSA/OSAS patients are able to fully reduce associated hidden healthcare costs and nonhealthcare costs

SOURCE: Analysis of economic costs of OSA/OSAS

# Further research could improve OSAS economic costs estimates and clarify the call to action to address the condition

NOT EXHAUSTIVE

| | Example areas for further research | Potential impact |
|---|---|---|
| **Diagnosis and treatment** | ▪ Assess compliance rates using electronic tracking system across different patient populations and treatment methodologies<br>▪ Understand treatment cost effectiveness by relevant segments of the population with OSA | ▪ Highlight the need to improve compliance<br>▪ Identify priority populations for commercial interests to build awareness |
| **Hidden health care costs** | ▪ Measure current prevalence of OSA<br>▪ Understand prevalence of disease directly associated with co-morbidities<br>▪ Better understand OSA attributable costs of co-morbidities including those from mild OSA | ▪ Current prevalence could have changed significantly from 1993 NEJM estimate<br>▪ Improved co-morbidities cost estimate for mild-severe OSA |
| **Traffic and workplace accidents** | ▪ Improve estimate of the cost of workplace accidents including the impact on Quality of Life<br>▪ Quantify the under-reporting of excessive sleepiness to estimate true OSAS prevalence<br>▪ Tighten estimate of traffic or workplace accident relative risk for people with OSA | ▪ Improved accuracy of economic cost estimate |
| **Loss of productivity** | ▪ OSA related estimates of the costs of absenteeism and poor on the job performance<br>▪ Explore potential legal liability costs | ▪ Increase cost estimate (note: not well estimated for other diseases) |

## Contents

Economic cost of OSAS

**Cost estimation approach**

# Economic cost of unmanaged moderate-severe OSA in the US estimated between ~$65B and $165B

PRELIMINARY

Partially sized
Not sized

**Estimated annual economic cost of OSA/OSAS in the US**
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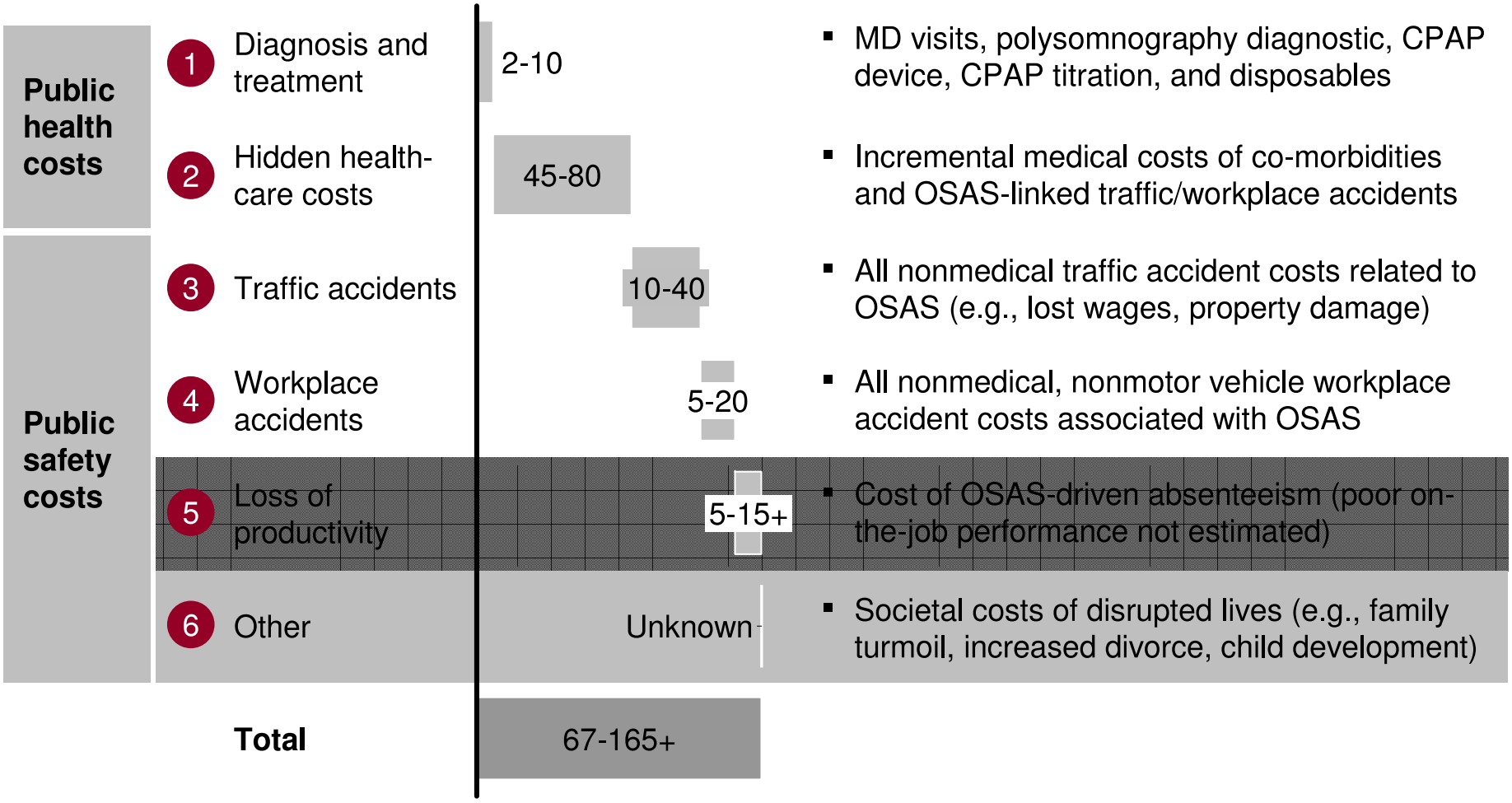



SOURCE: Academic papers, expert interviews, market reports

# Diagnosis and treatment is estimated to cost ~$2 - 10B per year, representing only small portion of overall economic costs of the disease

PRELIMINARY

Diagnosis & treatment costs = Cost of diagnosis × Patients diagnosed/year / % of positive diagnostics + **For CPAP:** (Initial treatment/ device cost × Newly treated patients + Ongoing treatment/ device cost × Compliant patients in treatment)

| | Min | Max | Key drivers of variance | Sensitivity[3] |
|---|---|---|---|---|
| **Moderate-severe OSA prevalence** | 6.5% | 8.5% | ▪ Unclear AHI threshold with demonstrated co-morbidities<br>▪ Proper normalization for factors such as sex, age and BMI<br>▪ Variability in prevalence measures for children and young adults | $3B |
| **Diagnosis / treatment costs[1]** | **Year 1**<br>$4.0K<br>**Years 2+**<br>$0.8K | $6.1K<br>$1.5K | ▪ Polysomnogram costs<br>▪ CPAP costs and necessity to calibrate<br>▪ Cost and replacement rate for disposable mask; potential recalibration | $5B |
| **Current diagnosis rate** | 15% | 20% | ▪ Availability of polysomnogram and PCP awareness and knowledge of OSAS<br>▪ Introduction of home testing kits | $3B |
| **Increase in prevalence/ diagnosis[2]** | **Prevalence**<br>+6 bps<br>**Diagnosis**<br>+90 bps | +15 bps<br>+160 bps | ▪ Increase of correlated conditions such as obesity/morbid obesity and diabetes<br>▪ Awareness of OSAS in general population and PCPs | $2B |

- Diagnosis and treatment of moderate-severe OSA is estimated to cost $2-10B per year
- High costs of diagnosis and year 1 treatment suggests need for cost-effective screening methods

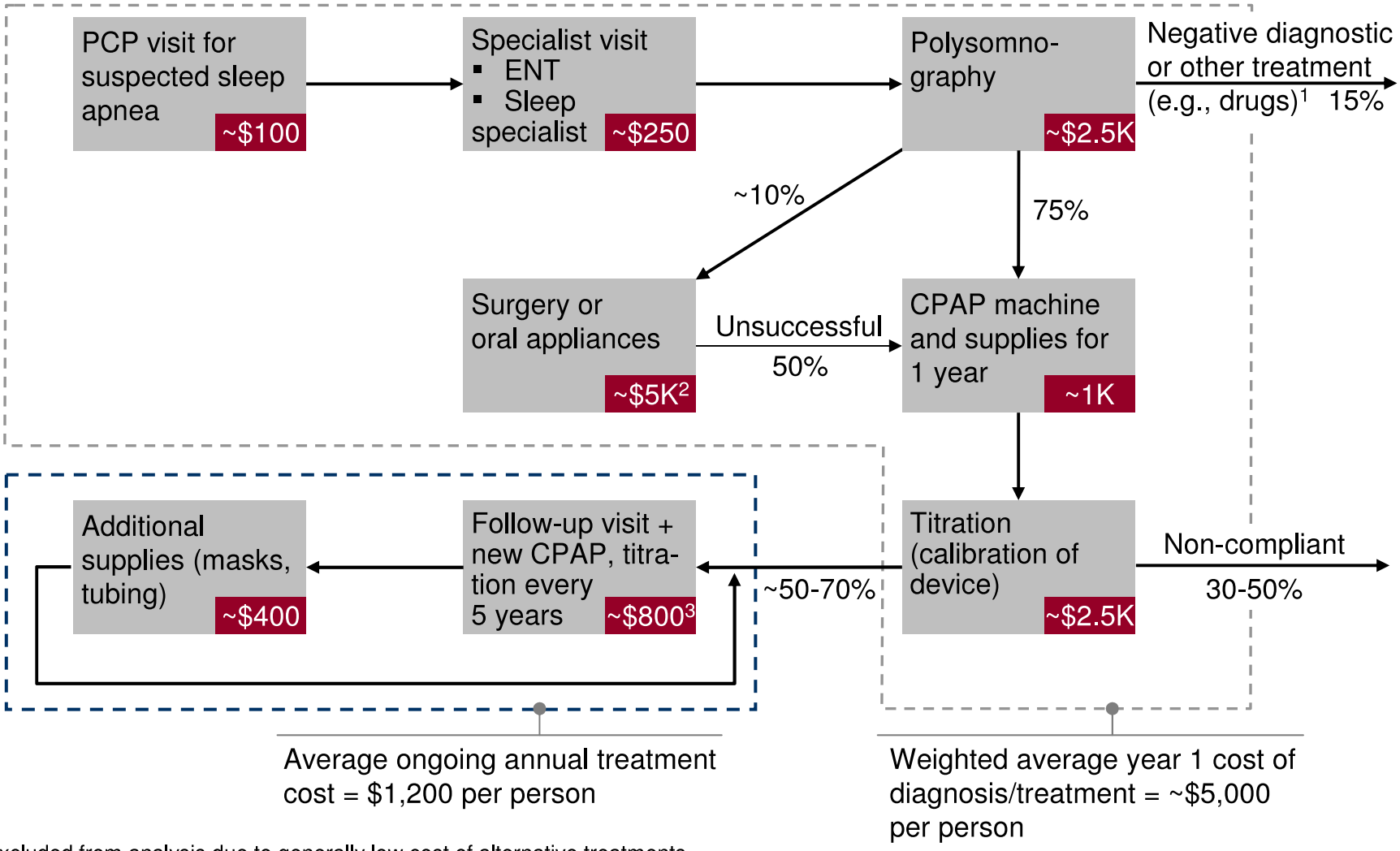
1 Diagnosis includes polysomnography and initial clinician visit. Treatment includes CPAP device with titration, disposable masks, follow-up clinician visits
2 Percentage point increase in basis points (1 bp = 1/100th of 1%)
3 Differences in OSAS attributable cost for min and max value of parameter (with all other parameters at maximum)

SOURCE: Experts interviews; Sassani A et al. Sleep 2004;27(3):453-458; Young T et al. N Engl J Med 1993; 328:1230-1235

# The majority of medical costs are driven by diagnosis and the first year of treatment

Activity — Cost per person

ESTIMATES




1 Excluded from analysis due to generally low cost of alternative treatments
2 Estimated weighted average from surgeries ($10K+) and oral appliances (~$1.5K)
3 Assumes 2-3 $70 follow-up visits per year and ~$2,500 polysomnography every 5 years for new titration

SOURCE: Academic paper; Interviews

# Hidden healthcare costs driven by associated co-morbidities & accidents are estimated to cost $45-80B per year

PRELIMINARY

Incremental healthcare costs of unmanaged OSAS = # of undiagnosed and non-compliant diagnosed patients x Incremental cost per unmanaged OSAS patient

| | Min | Max | Key drivers of variance | Sensitivity[1] |
|---|---|---|---|---|
| **Moderate-severe OSA prevalence** | 6.5% | 8.5% | ▪ Unclear AHI threshold with demonstrated co-morbidities<br>▪ Proper normalization for factors such as sex, age and BMI<br>▪ Variability in prevalence measures for children and young adults | $19B |
| **Incremental cost per person[2]** | ~$2700 | ~$3300 | ▪ Baseline US healthcare cost assumptions<br>▪ Potential biases in sample not properly controlled for (BMI, age, gender, healthcare utilization)<br>▪ Relative risk and cost assumptions for each OSAS-associated indication | $7B |
| **Percent undiagnosed** | 80% | 85% | ▪ Availability of polysomnogram and PCP awareness and knowledge of OSAS<br>▪ Introduction of home testing kits | ~$1B |
| **Non-compliance rate** | 30% | 50% | ▪ Period after diagnosis that compliance is measured; compliance drops over time due to discomfort and inconvenience<br>▪ CPAP technology used (developments have increased compliance) | ~$1B |

- Unmanaged OSA patients are estimated to cost the economy $45-80B per year in incremental healthcare costs
- Improving diagnosis and compliance rates will continue to lower the number and cost of unmanaged patients

1 Differences in OSAS attributable cost for min and max value of parameter (with all other parameters at maximum)
2 Incremental costs are increased to 2010 levels using average healthcare costs increases, and weighted to capture all age groups
Note: Incremental costs for population <18 years old are estimated using adult incremental costs adjusted for relative healthcare expenditures

SOURCE: Somers, Virend K et al. Journal of the American College of Cardiology 2008;52;686-717; Hillman DR et al. Sleep 2006;29(3):299-305; Sassani A et al. Sleep 2004;27(3):453-458; Kapur V et al. Sleep 1999;22(6): 749-755; Tarasiuk A Chest 2005; 128:1310-1314

# Unmanaged moderate-severe OSA is estimated to cost an incremental $2,700 to $3,000 in healthcare costs per person in the US

ESTIMATES

| | Kapur et al | Tarasiuk et al |
|---|---|---|
| **Study results (adults only)** | Mean annual HC costs of $2,720 pre-diagnosis vs. $1,384 for control subjects (in 1996) | Average 2.2x higher consumption of health-care resources 2 years prior to diagnosis vs. control subjects |
| **US annual OSA incremental medical cost in 1996** | $1,336 | $1,661[1] |
| **Healthcare spend CAGR, 1996-2007[2]** | 6.2% | |
| **Estimated 2010 incremental cost[3]** | ~$3,200 | ~$4,000 |

- Adults with unmanaged moderate-severe OSAS are estimated to incur $3,200-4,000 incremental annual healthcare costs
- Incremental cost for unmanaged OSA in people <18 estimated to be $1,000-1,300[4]
- **Age weighted avg incremental cost for entire population is ~$2,700-3,300**

1 Using similar baseline of $1384 as study 1 to control for differences in healthcare costs between US and Israel (study 2 - Tarasiuk)
2 Latest available year – Medical Expenditure Panel Survey
3 Assumes healthcare costs growth continues at same rate since 2007
4 Scaled based on difference between overall healthcare costs for adults compared to people under 18

SOURCE: Kapur V et al. Sleep 1999;22(6): 749-755 ; Tarasiuk A Chest 2005; 128:1310-1314

# OSAS-related traffic accidents are estimated to cost $12B - $39B per year

**We estimated automobile accident costs attributable to OSAS using the commonly adopted Levin formula**

$$\text{Accident cost attributable to OSAS}^{1} = \text{Total US cost of accidents } (C_T) \times \frac{\text{\# of crashes attributable to OSAS}}{\text{Total \# of crashes}} = C_T \times \frac{\text{OSAS prevalence (Relative risk}^2 - 1)}{\text{OSAS prevalence (Relative risk}^2 - 1) + 1}$$

\# of crashes attributable to OSAS = \# crashes involving people with OSAS − \# of crashes expected if these people didn't have OSAS

| | Min | Max | Key drivers of variance | Sensitivity[3] |
|---|---|---|---|---|
| **Relative risk[4]** | 2.1 | 3.0 | ▪ Population studied (e.g., gender, BMI, commercial drivers)<br>▪ Definition of accident (e.g., damage ≥ $500, personal injury)<br>▪ Source of accident details (e.g., self reported, state records) | $17B |
| **OSAS prevalence rate** | 3% | 5% | ▪ Uniform execution of polysomnogram<br>▪ Proper normalization for factors such as sex, age and BMI<br>▪ Variability in prevalence measures for children and young adults | $15B |
| **Total cost of accidents in US** | $407B | $449B | ▪ Estimated cost of reduced quality of life | $4B |

- Traffic accidents attributed to OSAS are estimated to cost the economy between $12B and $39B in 2010
- The relative risk of accidents varied significantly across groups of drivers (e.g., commercial)

1 US CPI and population growth used to scale figures to 2010 results
2 Assumed relative risk is equivalent to the odds ratio given low population probability of crash
3 Differences in OSAS attributable cost for min and max value of parameter (all other parameters at maximum)
4 Relative Risk - 95% confidence interval of Tregar et al meta-analysis of 15+ independent studies assessing the increased accident risk; Total Cost - 95% confidence interval of Tregar et al meta-analysis of 15+ independent studies assessing the increased accident risk; OSAS prevalence – epidemiological studies

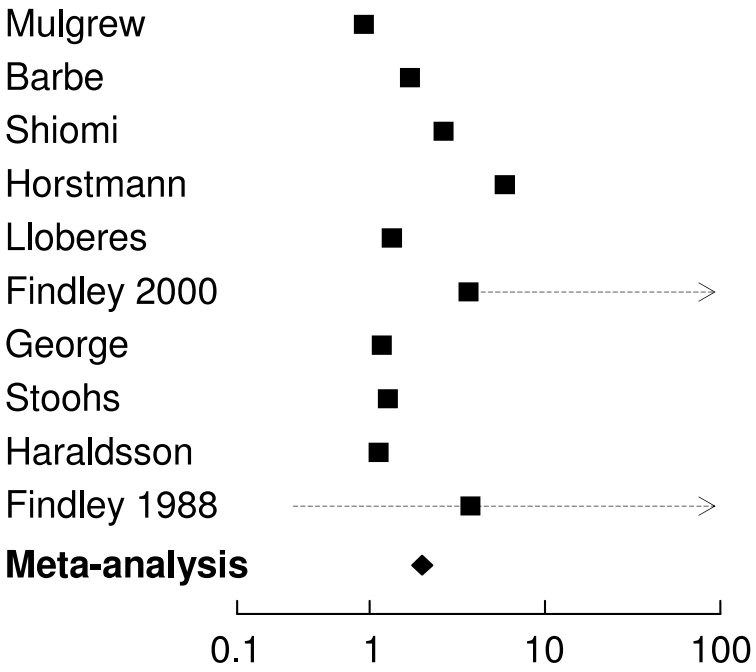
SOURCE: Young, T et al New England Journal of Medicine April 1993, National Safety Council, AAA, McKinsey

# A meta-analysis found that people with unmanaged OSA are ~2-3x more likely to have a traffic accident

**Treagear's analysis in "Obstructive Sleep Apnea and Risk of Motor Vehicle Crash: Systematic Review and Meta-Analysis" finds the relative risk of a crash in those with OSA of 2.43 (1.1 - 4.89)**

**Crash risk – OSA vs. control**

Relative risk with 95% confidence intervals




## Methodology

- Meta-analysis of 10 studies examining the relative risk of automobile crashes among those with OSA
- Paper inclusion criteria: sample size, use of control group, estimates of relative risks with confidence intervals, actual crash measurement (no simulations)
- Created a pooled estimate using a random-effects econometric regression

## Results

- A relative risk estimate of 2.43 (1.1-4.89, 95% confidence interval)

We assume a relative risk of 2.1-3.0 (scaled the difference between the 95% confidence interval upper/lower bounds and the mean to 25%)

SOURCE: Tregear S et al. J Clin Sleep Med 2009;5(6):573-581.

# OSAS-related workplace accidents cost the economy $7-22B per year

**We estimated workplace accident costs attributable to OSAS using the commonly adopted Levin formula**

Accident cost attributable to OSAS[1] = Total US cost of accidents ($C_T$) x (# of accidents attributable to OSAS / Total # of crashes) = $C_T$ x (OSAS prevalence (Relative risk[2] - 1) / OSAS prevalence (Relative risk - 1) +1)

(# accidents involving people with OSAS — # of accidents expected if these people didn't have OSAS)

| | Min | Max | Key drivers of variance | Sensitivity[3] |
|---|---|---|---|---|
| **OSAS prevalence rate** | 3% | 5% | ▪ Uniform execution of polysomnogram<br>▪ Proper normalization for factors such as sex, age and BMI<br>▪ Variability in prevalence measures for children and young adults | $8B |
| **Relative risk[4]** | 2.0 | 2.6 | ▪ Population studied (e.g., gender, BMI, occupation)<br>▪ Definition of accident (e.g., personal injury)<br>▪ Source of accident details (e.g, self reported, state records)<br>▪ Study of OSAS or EDS and snoring | $8B |
| **Total cost of accidents in US** | 293 | 316 | ▪ Estimated cost of reduced quality of life (e.g. discount rates) | $2B |

Estimates vary widely on the relative risk of a workplace accidents from OSAS, leading to large variance in costs estimates ($7-22B)

1 US CPI and population growth used to scale figures to 2010 results
2 Relative risk = . Assumed relative risk is equivalent to the odds ratio given low population probability of crash
3 Difference in between OSA attributable cost for min and max value of parameter (all other parameters at maximum)

SOURCE: Academic papers, National Safety Council, AAA, McKinsey

# Two pivotal studies inform the potential range in the total cost of workplace accidents (~$290 - $320B)

## Studies estimating workplace accident needed adjustment

**The raw studies were not comparable…**

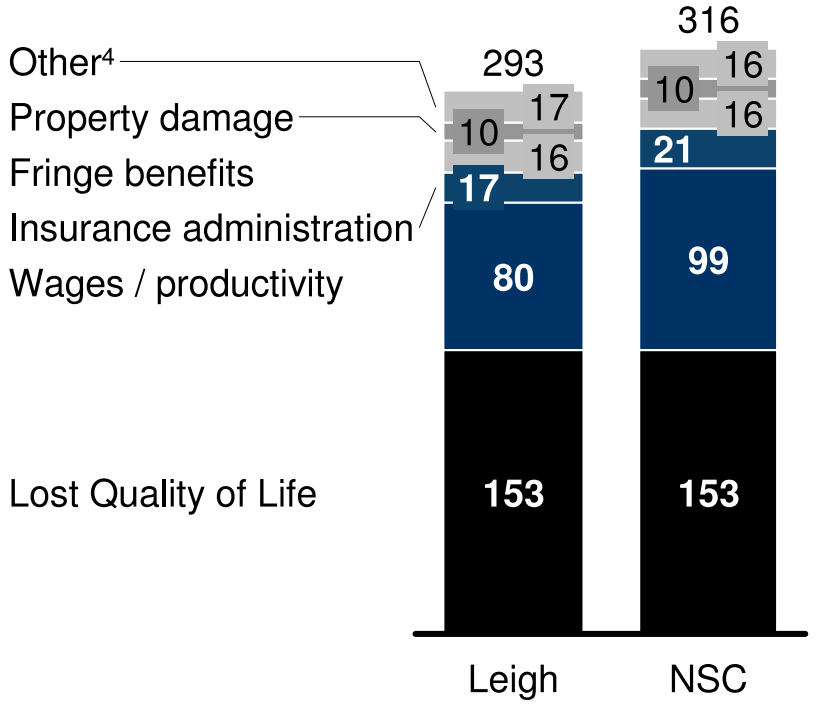
- Leigh et al found $145B in costs, but estimates were dated (1992)
- NSC calculated $163B in costs, but was not exhaustive in its methodology[1]
- Neither integrate quality of life impacts

**… Adjustments were made to better estimate OSAS-related costs**

- Scaled injury incidence, prices, and labor force size[2]
- Added quality of life costs
- Removed medical costs and motor-vehicle injury costs[3]

## The adjusted estimates of total workplace accident costs were relatively close

$ Billions, 2010




1 Both studies estimated wage/productivity losses, medical expenses, and administrative expenses, however Leigh also estimated property damage, home production, and employer costs
2 There were 51% fewer injuries in 2009 vs 1992 (Leigh)
3 Accounted for in "hidden healthcare costs" and "motor vehicle costs" buckets
4 Other includes time delays, police and fire services, workplace training, home production

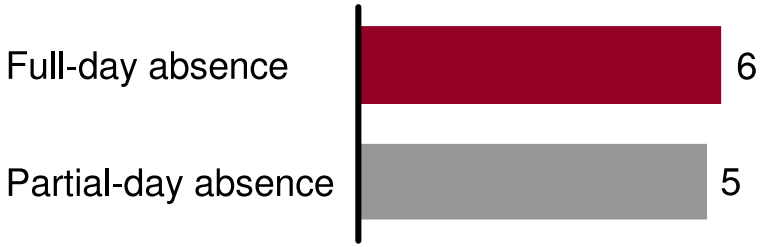
SOURCE: National Safety Council, Leigh, J. Arch Intern Med, Volume 157(14).July 28, 1997.1557-1568, Bureau of Labor Statistics

# OSAS-related lost productivity costs the economy at least $3-15B per year

## Workplace absences due to OSAS-related illness is estimated to cost $3 - 15B

**People with OSAS are more likely to be absent from work**

Odds ratios, OSAS vs. random sample




- No studies directly estimate OSAS-related absenteeism costs
- However, insomnia is thought to lead to an incremental 2 - 5 absentee days / year
- Assuming OSAS and insomnia cause comparable excessive daytime sleepiness, we estimate a total OSAS absenteeism cost of $3 - 15 B[1]

## OSAS likely costs society even more due to decreased job effectiveness

**People with OSAS are more likely to have lower productivity or be held back**

Odds ratios, OSAS vs. random sample


- The cost of fatigue-reduced productivity is very difficult to estimate
- We estimate employees with unmanaged OSAS are responsible for producing between $185B and $308B of GDP
- This suggests that the cost of reduced efficiency at work due to OSAS could exceed that of absenteeism

1 Assumes productivity of $57.5/person/hour, and 8 hours/missed workday
2 Examples include demotion, lack of promotion, negative changes in responsibility

SOURCE: Bureau of Labor Statistics, Omachi TA et al. SLEEP 2009;32(6):791-798; Godet-Cayré V. SLEEP 2006;29(2): 179-184.

# Moderate – severe OSA likely has other secondary effects that given their diffuse nature make it difficult to size

| | Observed effects | Possible economic impact |
|---|---|---|
| **Social effects** | ▪ Significantly poorer well-being and vitality reported by individuals with OSA:<br>– Depressed mood, and poor general mental health<br>– Marital unhappiness, up to and including severe family turmoil and divorce[1]<br>▪ Memory and judgment problems, irritability, difficulty concentrating, and personality changes<br>▪ Fatigue related accidents that are not traffic or workplace related | ▪ Economic impact of divorce<br>▪ Disconnected social network<br>▪ Loss of intimacy<br>▪ Economic cost of other accidents |
| **Child development** | ▪ Cognitive, behavioral, and psychosocial problems, including learning ability<br>▪ Reduced physical growth<br>▪ Higher probability of developing abnormal heart function | ▪ Increased risk of missed school attendance for health issues<br>▪ Lower education performance |

1 A 3x rate of divorce has been observed in individuals with unmanaged OSAS (controlling for obesity)

SOURCE: Baldwin et al., 2001; Grunstein et al., 1995

# Appendix

# OSA prevalence was adjusted to account for major growth drivers and is expected to continue to grow going forward

| Key drivers | Impact on OSA/OSAS prevalence |
|---|---|
| **Obesity** | ▪ While widely acknowledged, quantitative causal link between obesity and OSA is not well established<br>▪ Best estimate suggests that moderate – severe OSA is attributable to excess weight (BMI ≥ 24) in ~58% of adults cases<br>▪ CDC estimates growth in obese / overweight population from 1995 to 2009 at 1.5% p.a.<br>▪ 2010 OSA and OSAS prevalence estimates adjusted for obesity growth |
| **Age** | ▪ OSA/OSAS prevalence is generally twice or more as high in 60+ population vs. adults<br>▪ Used the latest available US population age group breakdown to estimate weighted average prevalence |

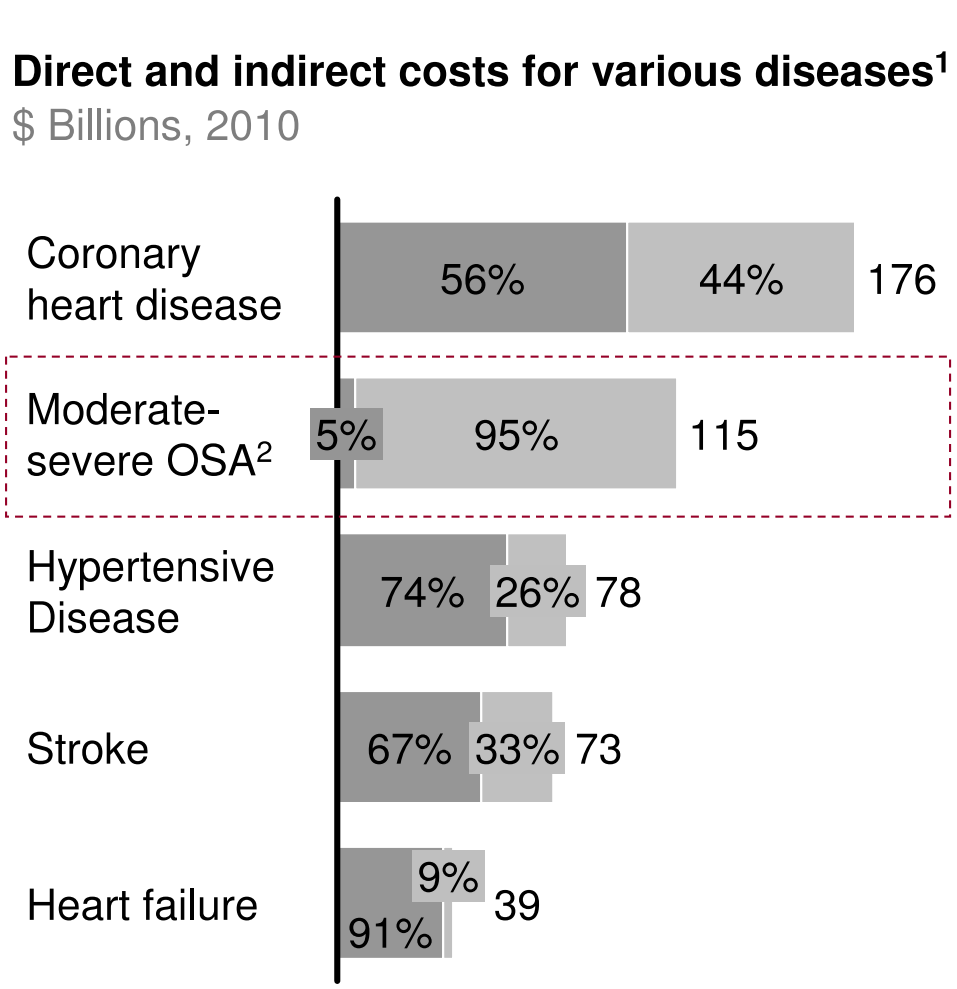
- Going forward, the aging population and obesity epidemic are likely to drive steady growth in the prevalence rate of moderate – severe OSA
- There is a clear need for further research to measure the current prevalence and potential for growth

SOURCE: Young T, J Applied Physiology, 2005;99-4:1592-1599; CDC BRFSS

# OSA has relatively high indirect costs suggesting that the marginal benefit of treating new patients could be higher than some other diseases

**Direct and indirect costs for various diseases[1]**

$ Billions, 2010




- Cardiovascular diseases (CVD) are relatively well understood and broadly treated
- As a result, direct costs are a larger percentage of total than for diseases like OSA[2]
- This could suggest that the marginal cost benefit of treating OSA could exceed that of CVD
- Further research could aim to find group(s) of people with OSA who would benefit most from treatment

1 Total cost estimation approach varies by disease in ways that cannot be easily compensated for (e.g., inclusion of mortality and/or morbidity costs). Estimates for diseases other than OSA largely included less costs.

2 Mid-range estimate of OSA costs. Assumes excess healthcare costs attributed to OSA (e.g., from co-morbidities) are indirect costs

SOURCE: American Heart Association; National Heart; Lung and Blood Institute

# The estimated total cost of moderate-severe OSA is dependent on several key inputs

ESTIMATES

Modeled range

## Sensitivity of key inputs[1]

**Prevalence is the most significant driver of variance**

**Diagnosis and compliance both need to be materially improved to drive economic benefits**

| Prevalence Percent | | Est. total cost $ Billions |
|---|---|---|
| OSA | OSAS | |
| 4.5 | 1.0 | 64 |
| 6.5 | 3.0 | 116 |
| 8.5 | 5.0 | 167 |
| 10.5 | 7.0 | 216 |
| 12.5 | 9.0 | 264 |

**Est. total cost of moderate-severe OSAS**
$ Billions

| Compliance rate | Diagnosis rate 10% | 15% | 20% | 25% | 30% |
|---|---|---|---|---|---|
| 30% | 167 | 166 | 166 | 165 | 165 |
| 50% | 165 | 163 | 161 | 159 | 157 |
| 70% | 162 | 159 | 156 | 153 | 150 |
| 90% | 160 | 156 | 152 | 147 | 143 |
| 100% | 159 | 154 | 149 | 144 | 139 |

1 Estimated total output assumes all other parameters at maximum

# The estimated economic savings assuming treatment is 100% effective varies significantly with total cost

ESTIMATES

$ Billions

| | Estimated total costs assuming treatment is 100% effective | | |
|---|---|---|---|
| | Current costs | 100% diagnosis and treatment[1]… | … and 100% compliance[2] |
| **Minimum estimate** | 70 | 54 | 26 |
| **Mid-range estimate** | 118 | 81 | 41 |
| **Maximum estimate** | 165 | 114 | 58 |

1 Savings are the difference between the current costs and the expected cost if all people with moderate – severe OSA were diagnosed and treated (assumes current compliance rates and that compliant treatment is 100% effective at removing all indirect public health and safety costs)

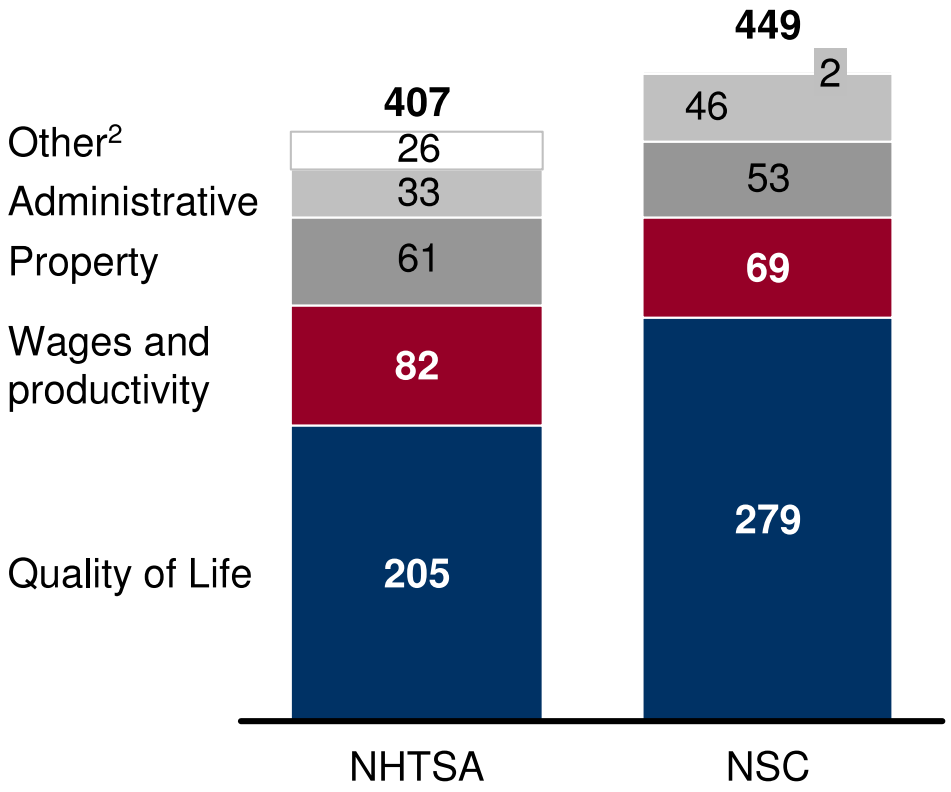
2 Incremental savings assuming that compliance with treatment was 100%

# The two sources that estimate the economic cost of accidents in the US vary most significantly in the quality of life estimate

ESTIMATES

## Estimated US economic cost of traffic accidents, by category, ages 25+[1]

$ Billions




## Key drivers of variance

- Economic impact on quality of life drives the majority of difference
- NHTSA and NSC used different cost / fatality when calculating Quality of Life[3] impact ($3.4M and $4.2M respectively)

1 We exclude those ages (16-25) or 25% of costs because they have lower OSAS prevalence and accidents are more often not related to OSAS
2 Other includes employer costs and travel delays
3 These assumptions account for 72% of the cost difference

SOURCE: National Highway Transit Safety Administration (2000), National Safety Council (2001), team analysis

# Fatigue-related resident medical error is estimated to have significant social costs, but OSAS is not a leading contributor

## Fatigue is a leading contributor to resident medical errors …

- An average of 98,000 patients die per year due to medical error, with an estimated cost of $308B[1]
- Residents average 80 hours / week and sleep deprivation has been repeatedly demonstrated to be a leading cause of medical error
  - Residents who worked more than 80 hours per week were 50% more likely to report making a significant medical error that led to an adverse patient outcome
  - Residents that work 15 – 20% fewer hours made 22% fewer serious medical errors (21% less medication errors and at least five times less diagnostic errors)
  - Residents that slept 6 more hours / week experience half the rate of attention failures
  - Sleep deprived surgical residents commit twice the errors in simulated laparoscopic surgery

## … However, we believe OSAS is a secondary contributor to intern fatigue

- Resident fatigue is driven primarily by excessive hours and long shifts
- The prevalence of OSAS is likely lower among medical residents as they are typically young, healthy, and have lower than average BMIs
- A literature search did not produce studies quantitatively linking OSAS to medical resident error
- Given the substantial costs involved, this area could benefit from additional study

1 (98,000 patients) x (value of a statistical life: $3.14M; estimate from NHTSA)

SOURCE: Institute of Medicine (2000), Grantcharov et al., (2001), Eastridge et al. (2003), Baldwin and Daugherty (2004), Lockley et al. (2004), Landrigan (2004), Harvard Work Hours and Safety studies