Overview

- Sociocultural context
- Obesity: Prevalence and consequences
- The relationship between obesity, weight loss and obstructive sleep apnea
- Preliminary Sleep AHEAD Data
Making the Office Environment Receptive

- Have gowns available that fit larger patients
- Buy a scale that can weigh all of your patients
- Use larger blood pressure cuffs when appropriate
- Provide some armless chairs in the waiting room
**BMI Calculation**

1. Multiply weight in pounds \( \times 703 = A \)
2. Divide \( A \) by height in inches = \( B \)
3. Divide \( B \) by height in inches = BMI

---

**Classification of Overweight and Obesity by BMI**

<table>
<thead>
<tr>
<th>Obesity Class</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt; 18.5</td>
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<tr>
<td>Normal Weight</td>
<td>18.5 – 24.9</td>
</tr>
<tr>
<td>Overweight</td>
<td>25.0 – 29.9</td>
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<tr>
<td>Obesity</td>
<td>30.0 – 34.9</td>
</tr>
<tr>
<td>I</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>35.0 – 39.9</td>
</tr>
<tr>
<td>Extreme Obesity</td>
<td>≥ 40</td>
</tr>
</tbody>
</table>

NHLBI Guidelines, 1998

---

**Prevalence of Overweight and Obesity Among US Adults**

- Extreme obesity (BMI ≥ 40)
- Overweight (BMI > or = 25)
- Obesity (BMI > or = 30)

Flegal, K et al, JAMA, 2002; Hedley, AA et al, JAMA, 2004; Ogden et al, JAMA, 2006
**Obesity Trends* Among U.S. Adults**

**BRFSS, 1989**

(*BMI ≥30, or ~30 lbs. overweight for 5' 4" person)*

<table>
<thead>
<tr>
<th></th>
<th>No Data</th>
<th>&lt;10%</th>
<th>10%–14%</th>
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**Obesity Trends* Among U.S. Adults**

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**BRFSS, 1992**

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<th>10%–14%</th>
<th>15%–19%</th>
</tr>
</thead>
</table>
Obesity Trends* Among U.S. Adults
BRFSS, 1993
(*BMI ≥30, or ~ 30 lbs. overweight for 5' 4" person)

No Data           <10%          10%–14%  15%–19%

Obesity Trends* Among U.S. Adults
BRFSS, 1994
(*BMI ≥30, or ~ 30 lbs. overweight for 5' 4" person)

No Data           <10%          10%–14%  15%–19%

Obesity Trends* Among U.S. Adults
BRFSS, 1995
(*BMI ≥30, or ~ 30 lbs. overweight for 5' 4" person)

No Data           <10%          10%–14%  15%–19%

Obesity Trends* Among U.S. Adults
BRFSS, 1996
(*BMI ≥30, or ~ 30 lbs. overweight for 5' 4" person)

No Data           <10%          10%–14%  15%–19%
**Obesity Trends* Among U.S. Adults**

*BRFSS, 1997*

(*BMI ≥30, or ~ 30 lbs. overweight for 5’4” person)*

<table>
<thead>
<tr>
<th>Data</th>
<th>&lt;10%</th>
<th>10%–14%</th>
<th>15%–19%</th>
<th>≥20%</th>
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*BRFSS, 1998*

(*BMI ≥30, or ~ 30 lbs. overweight for 5’4” person)*

<table>
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*BRFSS, 1999*

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<table>
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*BRFSS, 2000*

(*BMI ≥30, or ~ 30 lbs. overweight for 5’4” person)*

<table>
<thead>
<tr>
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<th>≥20%</th>
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<tbody>
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</tbody>
</table>
Obesity Trends* Among U.S. Adults
BRFSS, 2001
(*BMI ≥30, or ~ 30 lbs. overweight for 5’4” person)

Obesity Trends* Among U.S. Adults
BRFSS, 2002
(*BMI ≥30, or ~ 30 lbs. overweight for 5’4” person)

Obesity Trends* Among U.S. Adults
BRFSS, 2003
(*BMI ≥30, or ~ 30 lbs. overweight for 5’4” person)

Obesity Trends* Among U.S. Adults
BRFSS, 2004
(*BMI ≥30, or ~ 30 lbs. overweight for 5’4” person)
Health Consequences of Obesity

- Cardiovascular disease
- Type 2 diabetes
- Hypertension
- Dyslipidemia
- Ischemic stroke
- Sleep apnea
- Degenerative joint disease
- Some types of cancer
- Gallstones
- Gynecologic irregularities


Health Benefits of Weight Loss

Weight loss of 5%-10% in obese individuals with type 2 diabetes, hypertension or dyslipidemia resulted in:

- Improved glycemic control
- Reduced blood pressure
- Improved lipid profile


Visceral Adiposity: Higher Risk for Metabolic Syndrome

Patients With High Visceral Adiposity Have Significantly Higher Risk Factors for Metabolic Syndrome Than Non-Obese Patients

*Significantly different from non-obese patients.
†Significantly different from obese patients with low levels of deep abdominal fat, \( P<0.05 \).


Patients With High Visceral Adiposity Have Significantly Higher Risk for Metabolic Syndrome Than Non-Obese Patients

Visceral Adiposity: Higher Risk for Metabolic Syndrome

Obesity and OSA

- Two-thirds of OSA participants are obese
  (Guilleminault C et al. Chest, 1998)

- One SD increase in BMI is associated with a 4-fold increase in RDI (Young T et al. NEJM, 1993)

- 40% of weight-loss patients have RDI>5

Weight Loss and OSA

- Weight losses of 9% to 20% have been associated with reductions in AHI of 30% to 74%
  (Strobel RJ & Rosen RC. Sleep, 1996.)

- A 1% change in weight is associated with a 3% change in AHI
  10% ↓ in weight is associated with a 26% ↓ in AHI
  10% ↑ in weight is associated with a 32% ↑ in AHI
  (Peppard et al. JAMA 2000.)
The Sleep Heart Health Study

- Longitudinal cohort study of the cardiovascular consequences of OSA
- Sought to determine the relationship between change in weight and progression or remission of SDB
- 2986 male and female subjects (mean age=62 years; mean BMI=28.75)
- Severity of OSA measured by polysomnography, with follow-up at year 5
  - Mean male AHI at baseline=6.3
  - Mean female AHI at baseline=2.8


The Sleep Heart Health Study, Results

- Men were more likely to have an increase in AHI over time
  - Male AHI increase: 3.4 ± 12.4
  - Female AHI increase: 2.2 ± 9.0


The Sleep Heart Health Study, Results

- Both men and women had a greater increase in AHI with weight gain than a decrease in AHI with weight loss
- OSA ultimately progressed over time, even in those who maintained a stable weight


Effects of Weight Loss and OSA

- Graph showing changes in weight and AHI

Smith PL et al., Ann Intern Med (1985)
Weight Loss and AHI

- No RCT has assessed the effects of weight loss on OSA.
- Among weight-loss treated (n=15) and control (n=8) patients, a 9% weight loss was associated with 47% reduction in AHI.
- Across uncontrolled studies, there was no significant relationship between weight loss and the change in AHI.

Rationale

- Weight loss is frequently recommended for obese patients with obstructive sleep apnea (OSA), but the empirical foundation for this recommendation is not well substantiated.
- Weight loss in sleep apneics improves but does not eliminate sleep-disordered breathing and the degree of improvement is not correlated with weight loss.
Overnight polysomnograms were performed in the participants’ homes

The following signals are recorded on a data acquisition system (Compumedics PS2):
- Electroencephalogram (C3A2, C4A1)
- Bilateral electrooculograms (referenced to A2 and A1 respectively)
- Bipolar submental electromyogram
- Movements of the rib cage and abdomen
- **Nasal pressure as an index of airflow**
- Body position
- Pulse oximetry
- Electrocardiogram
- Presence or absence of snoring

<table>
<thead>
<tr>
<th>Gender (% female)</th>
<th>Sleep AHEAD Participants (N = 306)</th>
<th>Look AHEAD (not Sleep AHEAD, 4 Sites) (N = 1012)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>59.8%</td>
<td>60.2%</td>
<td>0.91</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Sleep AHEAD Participants (N = 306)</th>
<th>Look AHEAD (not Sleep AHEAD, 4 Sites) (N = 1012)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>61.4 ± 6.5</td>
<td>58.7 ± 6.9</td>
<td>&lt;.0001</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Race:</th>
<th>Sleep AHEAD Participants (N = 306)</th>
<th>Look AHEAD (not Sleep AHEAD, 4 Sites) (N = 1012)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black/Afr. Am.</td>
<td>19.0%</td>
<td>19.5%</td>
<td></td>
</tr>
<tr>
<td>Am. Ind./Nat. Am.</td>
<td>1%</td>
<td>0.4%</td>
<td></td>
</tr>
<tr>
<td>Asian/Pac. Island</td>
<td>1.6%</td>
<td>0.5%</td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>3.3%</td>
<td>4.6%</td>
<td></td>
</tr>
<tr>
<td>Mixed/Other White</td>
<td>2.0%</td>
<td>1.9%</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>73.1%</td>
<td>73.1%</td>
<td></td>
</tr>
</tbody>
</table>

**Subject Characteristics**

**Sleep AHEAD**

<table>
<thead>
<tr>
<th>Total</th>
<th>Control</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>101.7 ± 18.0</td>
<td>101.3 ± 17.1</td>
</tr>
<tr>
<td>AHI (events/hr)</td>
<td>29.8 ± 19.5</td>
<td>29.8 ± 18.8</td>
</tr>
<tr>
<td>Age</td>
<td>61.4 ± 6.5</td>
<td>61.2 ± 6.4</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>115.0 ± 13.0</td>
<td>114.8 ± 12.0</td>
</tr>
</tbody>
</table>
Sleep Disordered Breathing in Obese Patients with Type 2 Diabetes (N=306)

- AHI < 5: 40.7% Severe
- AHI 5-14.9: 21.9% Mild
- AHI 15-29.9: 34.8% Moderate
- AHI > 30: 2.6% Mild

Undiagnosed Sleep Disordered Breathing in Obese Patients with Type 2 Diabetes (N=281)

- AHI < 5: 40.2% Severe
- AHI 5-14.9: 22.8% Mild
- AHI 15-29.9: 34.2% Moderate
- AHI > 30: 2.8% Mild

Undiagnosed, Unscreened Sleep Disordered Breathing in Obese Patients with Type 2 Diabetes (N=203)

- AHI < 5: 3.0% Severe
- AHI 5-14.9: 19.2% Mild
- AHI 15-29.9: 35.0% Moderate
- AHI > 30: 42.9% Severe

AHI Category

<table>
<thead>
<tr>
<th>AHI Category</th>
<th>AHI 5-14.9 (N=67)</th>
<th>AHI 15-29.9 (N=108)</th>
<th>AHI ≥30 (N=123)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHI</td>
<td>10.5 ± 2.9a</td>
<td>22.2 ± 4.7b</td>
<td>49.0 ± 15.9c</td>
</tr>
<tr>
<td>Gender</td>
<td>65.7%a</td>
<td>75%b</td>
<td>42.3%c</td>
</tr>
<tr>
<td>Body Habitus:</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Weight (kg)</td>
<td>95.3 ± 16.1a</td>
<td>98.6 ± 17.3a</td>
<td>107.8 ± 18.4a</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>34.5 ± 5.3a</td>
<td>36.3 ± 5.9ab</td>
<td>39.2 ± 18.9b</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>109.7 ± 10.2a</td>
<td>113.8 ± 12.6ab</td>
<td>119.2 ± 13.4c</td>
</tr>
<tr>
<td>Age (years)</td>
<td>60.2 ± 7.1</td>
<td>61.6 ± 5.7</td>
<td>61.8 ± 6.7</td>
</tr>
</tbody>
</table>
AHI Category

<table>
<thead>
<tr>
<th>AHI Category</th>
<th>AHI 5-14.9 (N=67)</th>
<th>AHI 15-29.9 (N=108)</th>
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</thead>
<tbody>
<tr>
<td>Diabetes Status:</td>
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</tr>
<tr>
<td>% on insulin</td>
<td>16.4%</td>
<td>13.3%</td>
<td>10.3%</td>
</tr>
<tr>
<td>Fasting glucose (mg/dl)</td>
<td>155.1 ± 55.9</td>
<td>148.7 ± 36.9</td>
<td>155.5 ± 45.6</td>
</tr>
<tr>
<td>HbA1C (%)</td>
<td>7.2 ± 1.2</td>
<td>7.2 ± 1.0</td>
<td>7.2 ± 1.1</td>
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<tr>
<td>Race:</td>
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<tr>
<td>Black/Afr. Am</td>
<td>23.9%</td>
<td>19.0%</td>
<td>16.7%</td>
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<td>Am. Ind./Nat. Am.</td>
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<tr>
<td>Missing</td>
<td>3.0%</td>
<td>1.0%</td>
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<tr>
<td>Mixed/Other</td>
<td>3.0%</td>
<td>1.9</td>
<td>1.6%</td>
</tr>
<tr>
<td>White</td>
<td>65.7%</td>
<td>71.4%</td>
<td>77.0%</td>
</tr>
</tbody>
</table>

Results

Correlations were conducted on AHI as a continuous variable.

AHI was strongly related to:
- waist circumference ($r = .349$)
- neck circumference ($r = .303$)
- BMI ($r = .263$)
- gender ($r = .227$)

AHI was not related to any sleep related symptoms.

Multiple Regression

- Variables that were associated with AHI were included in a multiple regression predicting AHI as a continuous variable.
- An exploratory stepwise procedure was used while controlling for BMI.
- Standardized beta coefficients were used to assess relative contributions.
  - Neck circumference & symptom questions did not predict AHI.
  - Waist circumference = best predictor ($p<.05; \beta=.28$)
  - Gender (male) = second best predictor ($p<.05, \beta=6.79$)

Multiple Logistic Regression

- The same variables were used in a multiple logistic regression to predict severe OSA (AHI ≥ 30) when AHI was treated as a categorical variable.
  - The only significant predictor was gender (male: $OR = 3.2; 95\% CI 1.7-5.9; p < .001$)
  - There was a trend for BMI ($OR = 1.07; 95\% CI .99-1.14; p = .07$)
Mean AHI Change

-4 -2 0 2 4 6 8 10 12 14

1-year 2-year

n=86 n=106
ns106 ns52

Mean AHI Change

* (p<.0001) (p=.08)

1-year 2-year

n=32

Recent Findings

Martinez-Rivera, et al., *Obesity*, 2008

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>Age (years)</td>
<td>51.9 ± 9.5</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>31.0 ± 5.9</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>104.3 ± 13.58</td>
</tr>
<tr>
<td>Hip circumference (cm)</td>
<td>108.1 ± 13.57</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.96 ± 0.06</td>
</tr>
<tr>
<td>Neck circumference (cm)</td>
<td>41.7 ± 4.07</td>
</tr>
</tbody>
</table>

The study group contained 102 patients referred to our sleep respiratory disorders center with suspected obstructive sleep apnea syndrome. Values are shown as mean ± SD.

Martinez-Rivera, et al., *Obesity*, 2008

<table>
<thead>
<tr>
<th>Variable</th>
<th>OSAS</th>
<th>No OSAS</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>53 ± 10</td>
<td>49.5 ± 8.5</td>
<td>0.03</td>
</tr>
<tr>
<td>AHI</td>
<td>38.9 ± 23.4</td>
<td>4.86 ± 3.46</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>31.4 ± 5.5</td>
<td>31.02 ± 6.8</td>
<td>0.66</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>106.3 ± 2.4</td>
<td>100.7 ± 14.9</td>
<td>0.009</td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
<td>0.98 ± 0.06</td>
<td>0.94 ± 0.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Neck circumference (cm)</td>
<td>42.5 ± 3.6</td>
<td>40.5 ± 4.6</td>
<td>0.001</td>
</tr>
<tr>
<td>Sex, male, n (%)</td>
<td>105 (84.7%)</td>
<td>47 (39.1%)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Results are expressed as mean ± s.d., unless otherwise indicated. Values for P obtained by Student’s t-test for quantitative variables and χ² test for the qualitative variable sex.

AHI, apnea-hypopnea index; OSAS, obstructive sleep apnea syndrome.
Summary

• Obesity increases the risk of OSA
• The role of modest weight loss is improving OSA is less clear
• Obese patients with T2DM appear to be at high risk for undiagnosed sleep apnea
• Male obese patients with T2DM are at greatest risk of severe OSA

Martinez-Rivera, et al., *Obesity*, 2008

<table>
<thead>
<tr>
<th>Table 5: Odds ratio of the indicated variables for development of OSAS according to a multivariate logistic regression model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variable</strong></td>
</tr>
<tr>
<td>Waist-to-hip ratio</td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Neck circumference (cm)</td>
</tr>
<tr>
<td>Sen</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
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Acknowledgements

• **University of Pennsylvania**
  – Samuel Kuna, M.D.
  – Tom Wadden, Ph.D.
  – Allan Pack, M.D., Ph.D.
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  – Mary Jones Parker
  – Nida Cassim
  – Sakhena Hin

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  – David Kelley, M.D.
  – Jacqueline Wesche-Thobaben
  – Laura Waterstram

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  – Rena Wing, Ph.D.
  – Renee Bright
  – Marie Kearns

• **Columbia University**
  – Gary Zammit, Ph.D.
  – F. Xavier Pi Sunyer, M.D.
  – Jennifer Patricio
“Well, I see my time is up...”