

The Energy Gap Model: A Common Metric for Evaluating Policy Strategies for Childhood and Adolescent Obesity Prevention

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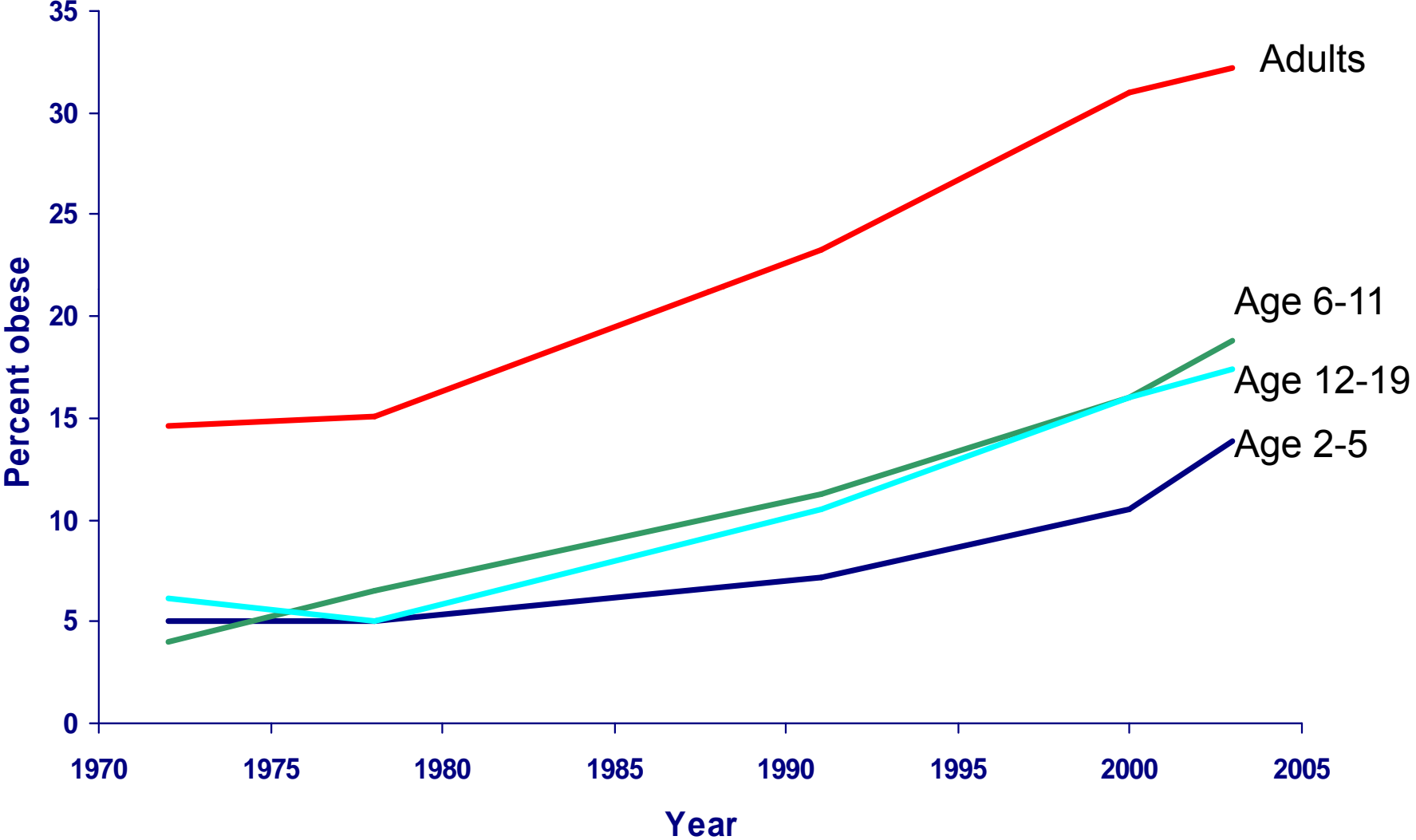
Columbia Mailman School of Public Health

July 23, 2009

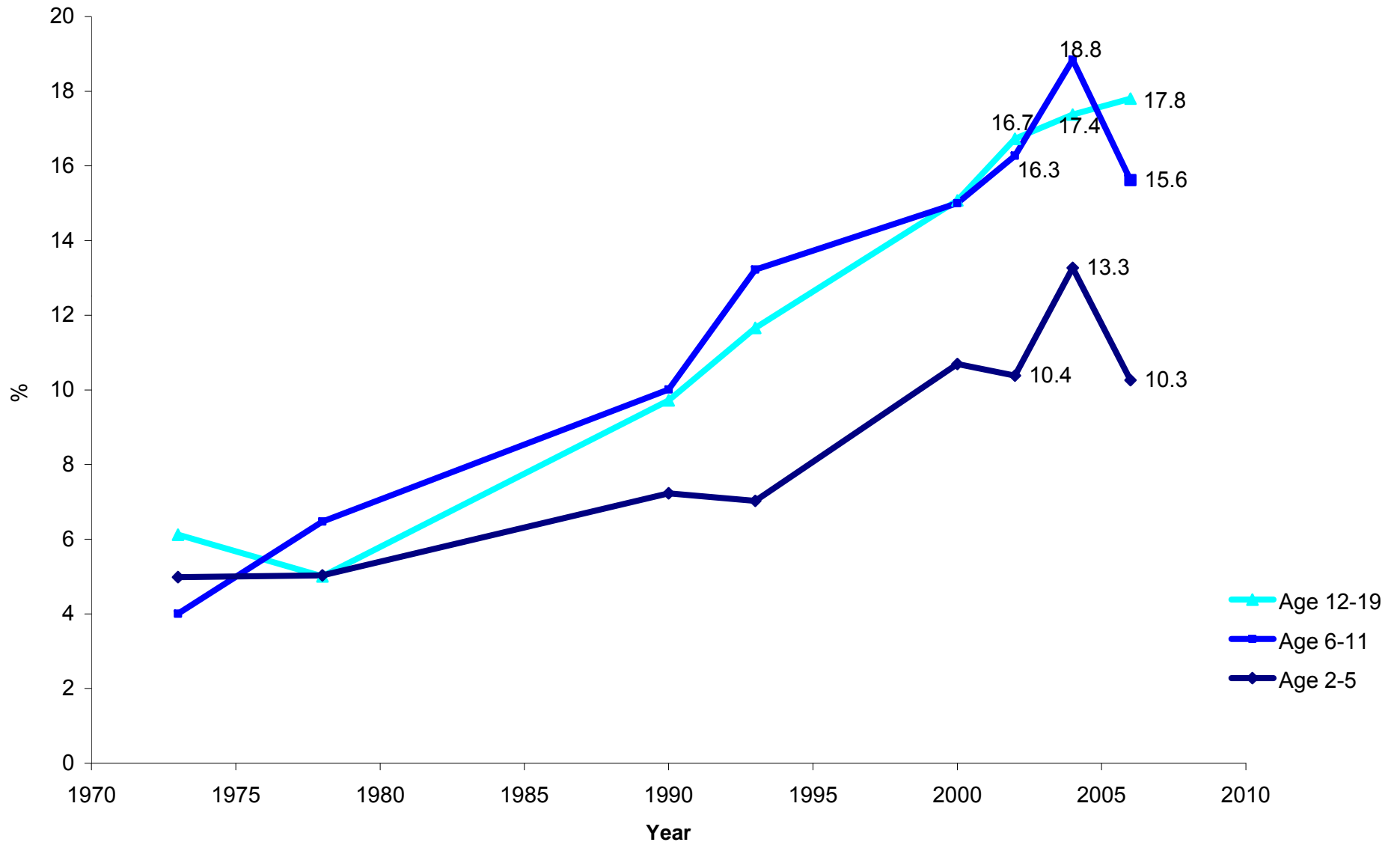
Saskatoon, Saskatchewan

Canada

US Obesity Trend

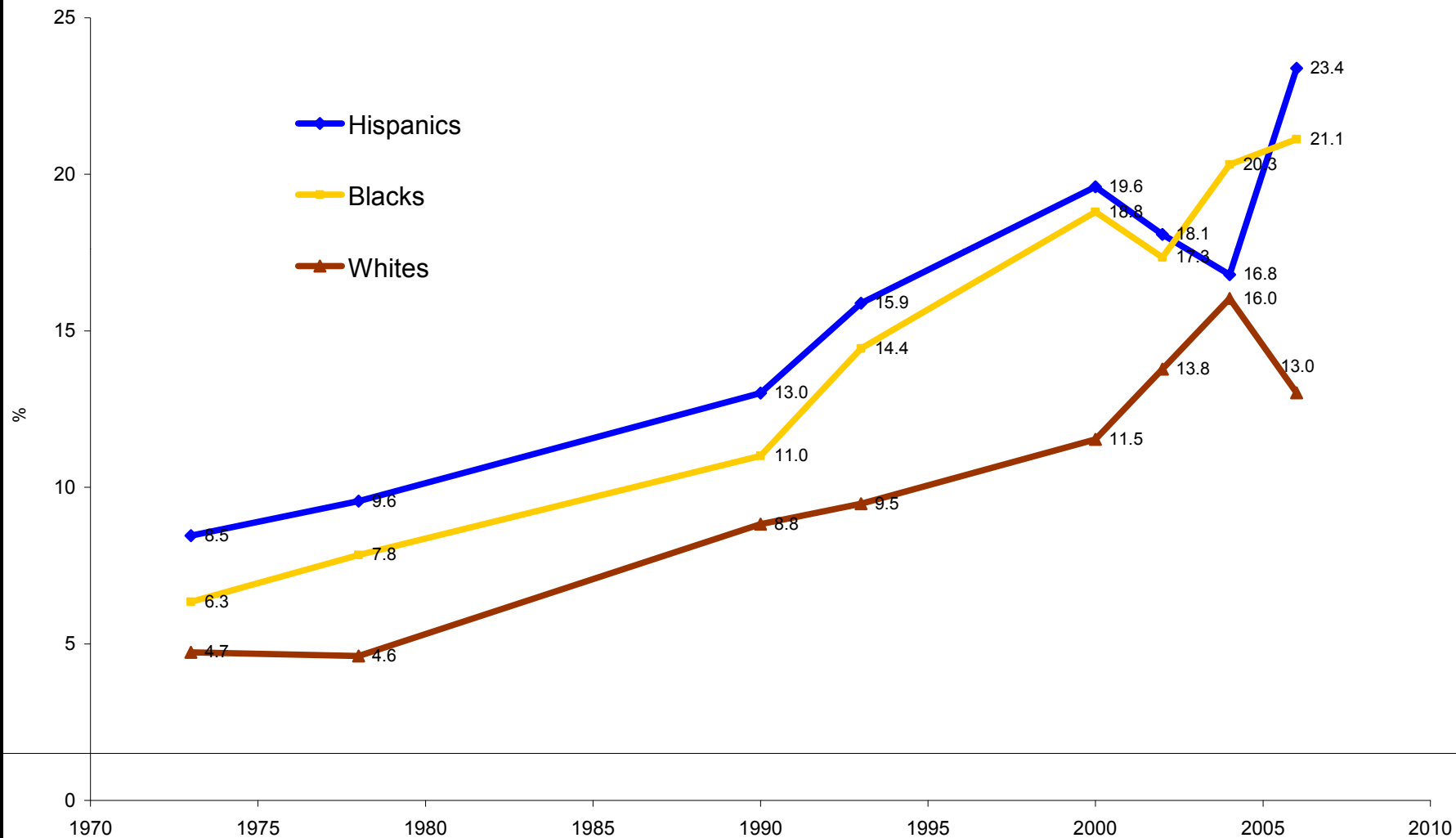


% Obese, by Agegroup, 1970-2006



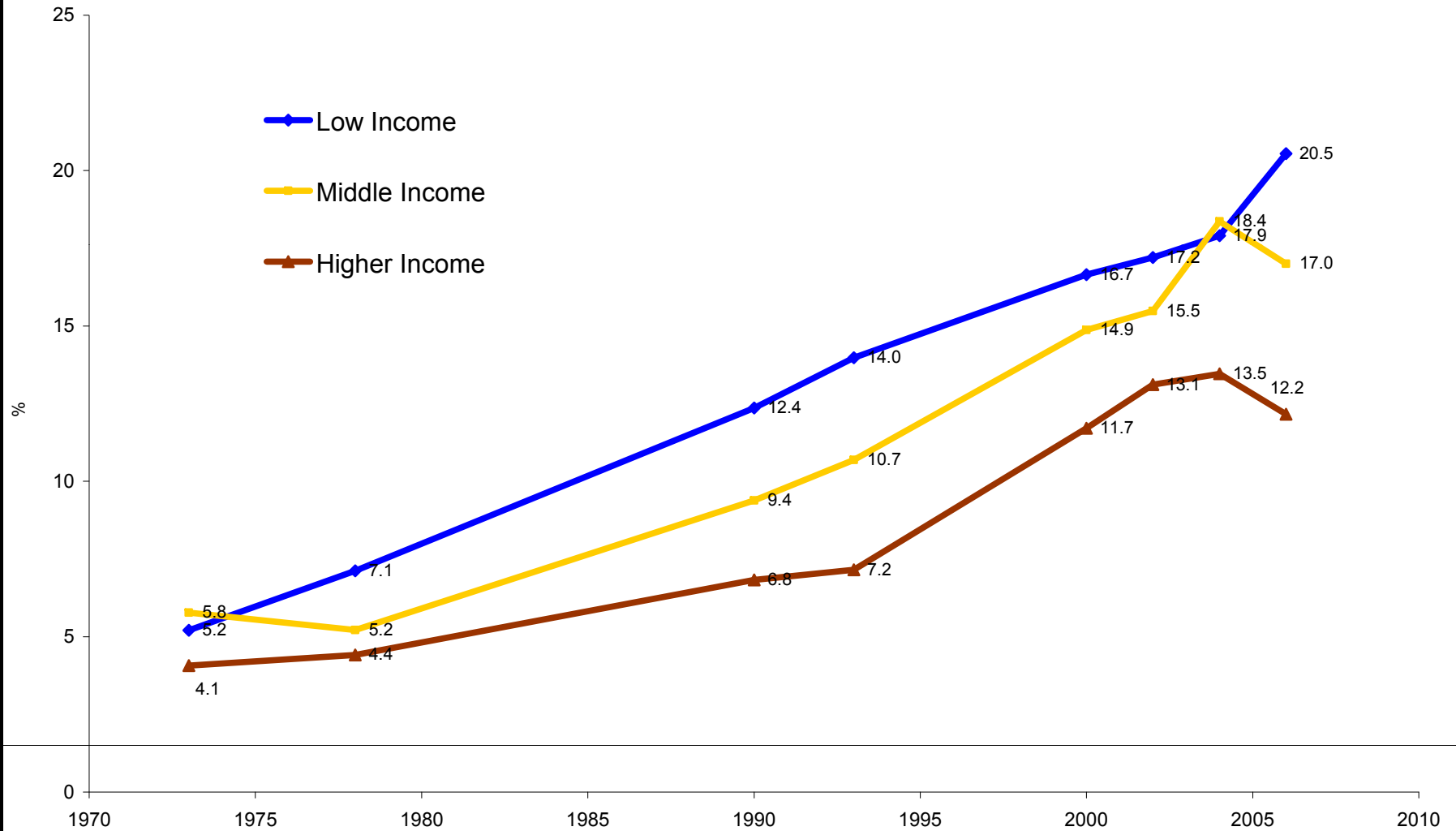
Disparities –by Race/Ethnicity

%Obese, Age 2-19, by Race-Ethnicity

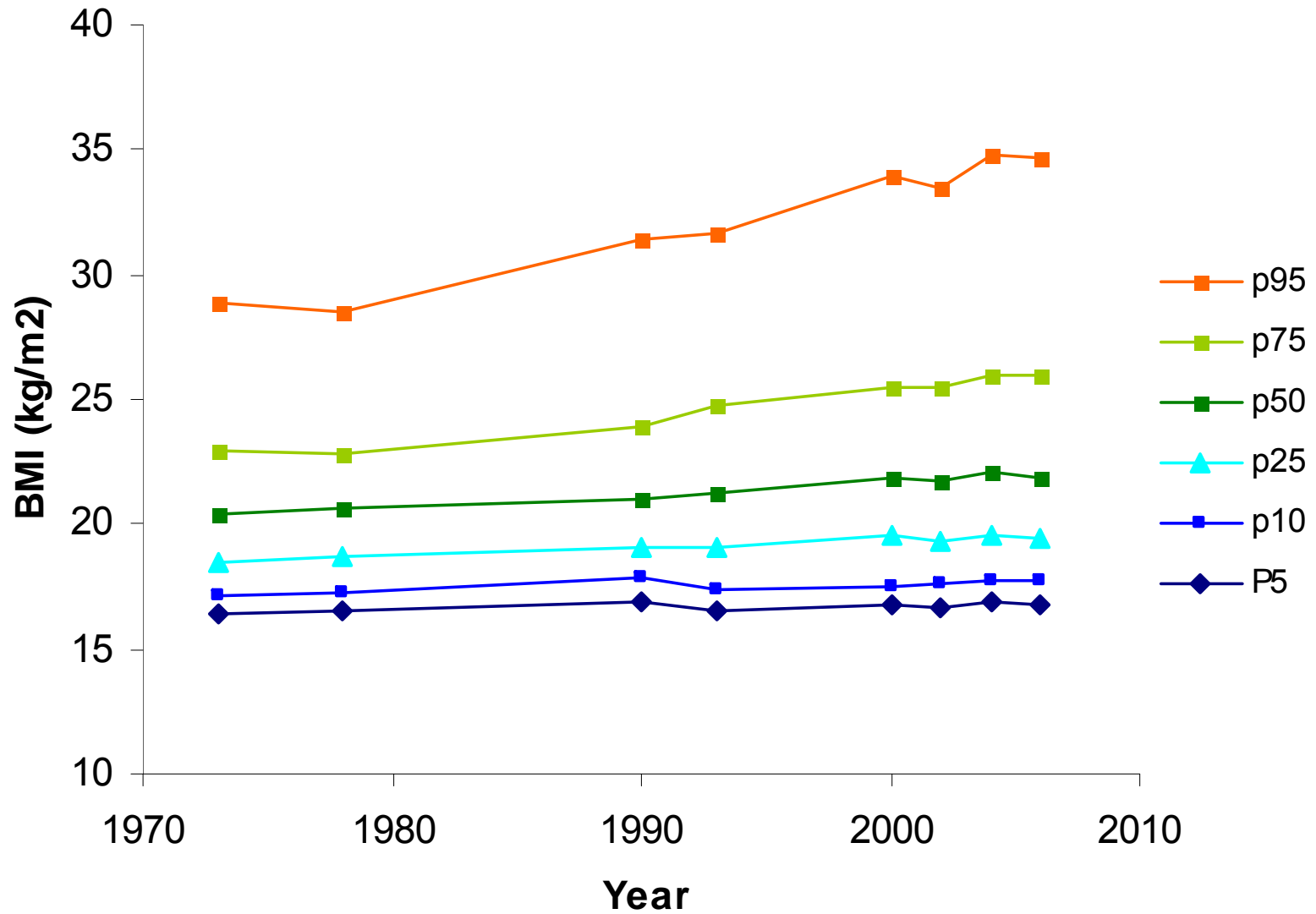


Disparities – by Income

%Obese, Age 2-19, by Income



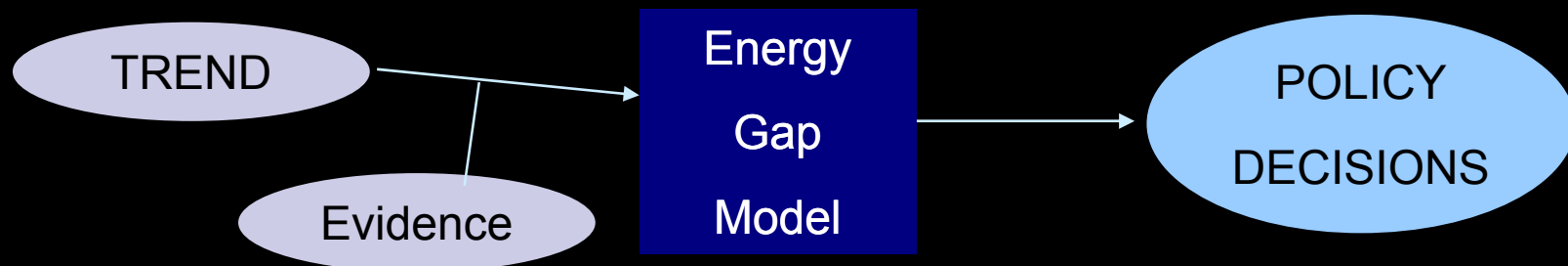
BMI Percentile Change, Age 12-19



Why Model Childhood Obesity Epidemic using a Energy Gap Framework?

-linking trend and evidence to inform decision making

- Explain : What is the magnitude of energy imbalance that is driving the shift in body size distribution?
- Consolidate prevailing wisdom with experimental evidence
- Forecast: where is it going and what is the impact?
 - Goal setting and benchmarking
- Illuminate core uncertainties: what are the knowledge gaps most critical for decision making?
- Leverage surveillance data
- Comparative effectiveness of interventions

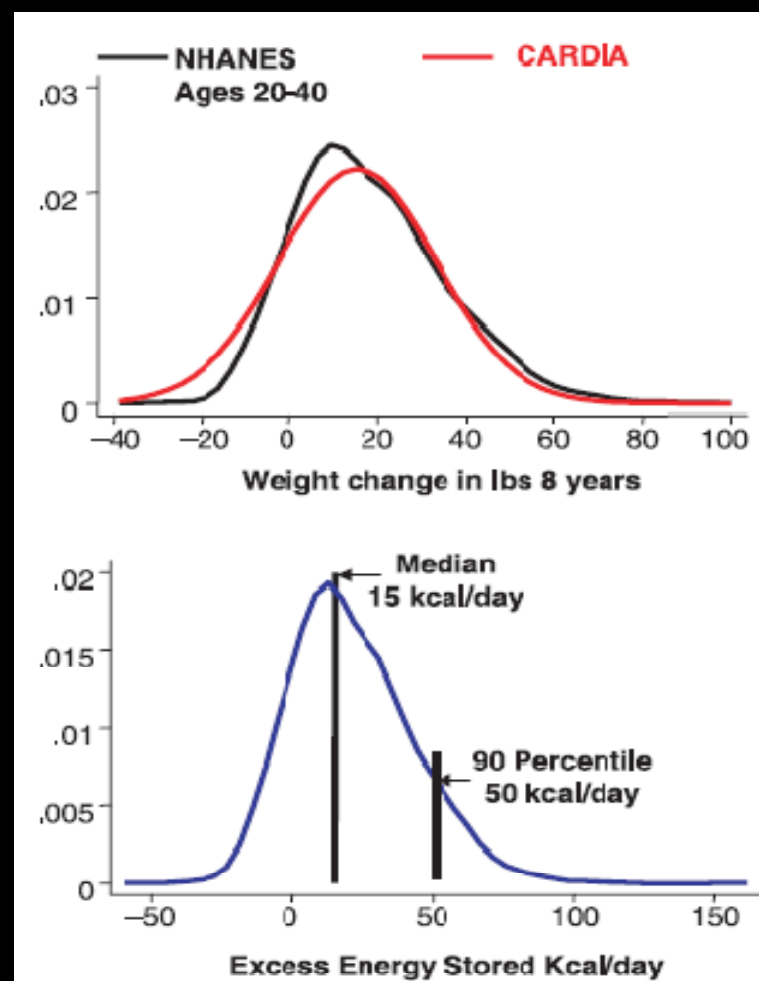




How large is the energy gap underlying the childhood obesity trend in the US?

Energy Gap in Adults: Hill et al. 2003

- Population-wide weight gain for adults age 20-40 averages 1.8-2 lb/year.
- Assuming 1 lb ~3500 kcal stored, reducing energy gain by 50 kcal/d offsets weight gain in 90% of population.
- As energy stored at ~50% efficiency, most weight gain can be eliminated by 100 kcal/d expenditure or intake
- But this approach ignores increase in expenditure with weight gain=>underestimate



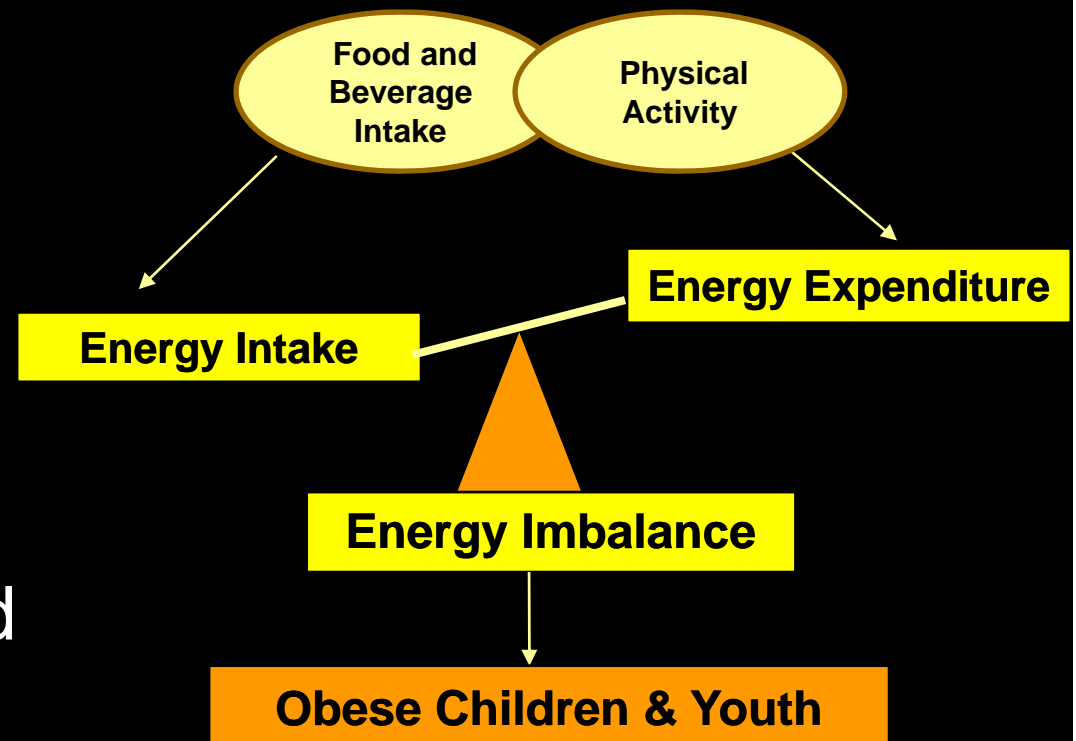
*Hill JO, Wyatt HR, Reed GW, Peter JC. Obesity and the environment: where do we go from there? Science 2003; 299: 853-5

Energy Gap Framework: Rationale

- Excess weight gain during growth is a result of energy intake exceeding expenditure.
- Dietary intake, physical activity, and relative weight gain measures are often expressed in different metrics
- Need for common metric for evaluating comparative effectiveness between interventions.
- Measuring underlying drivers of population weight shift with a common metric will inform surveillance, goal setting and benchmarking progress.

Energy Gap:

- **Definition:**
Imbalance between calories children consume each day and calories required to support normal growth, physical activity, and body function.



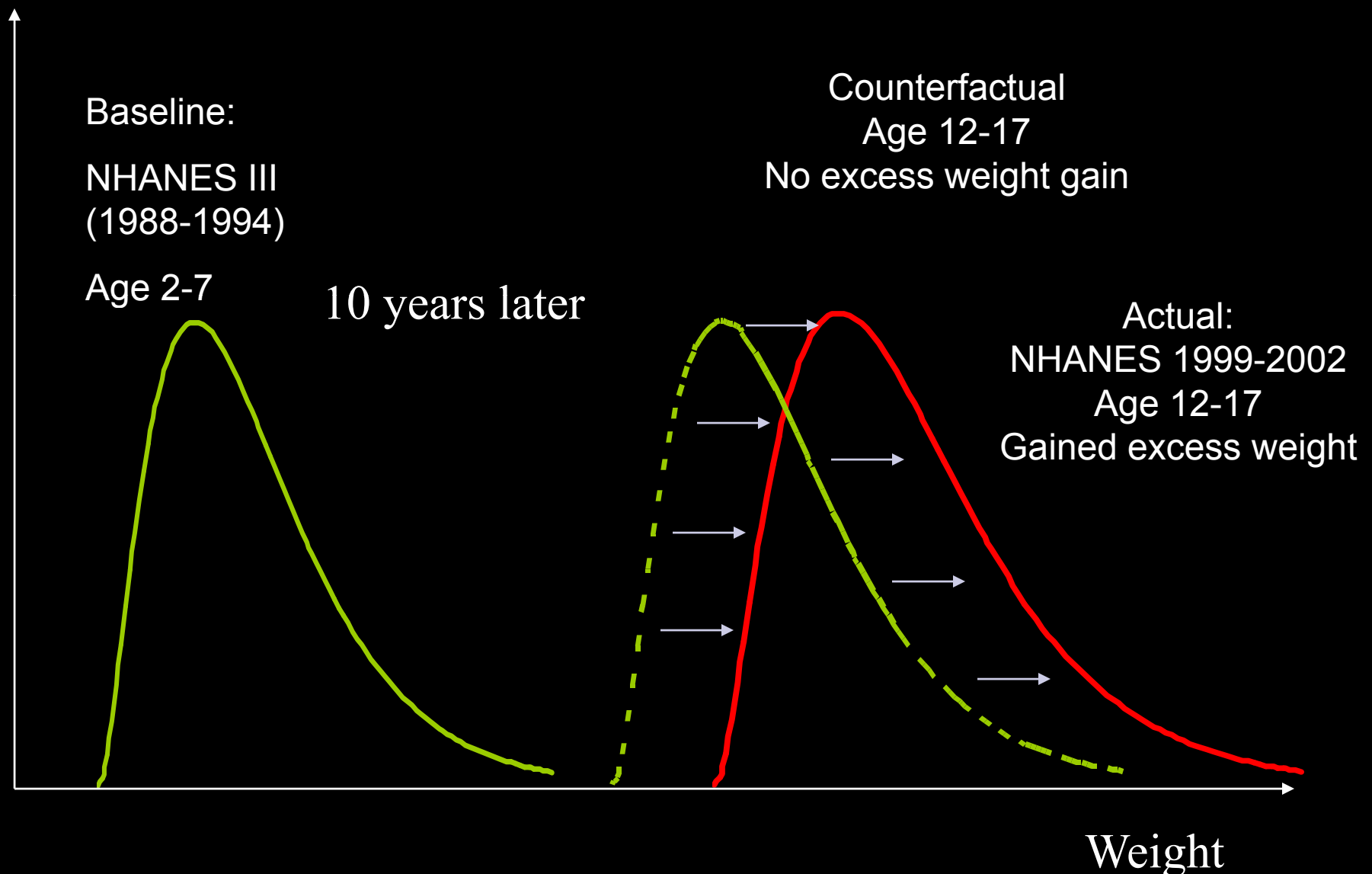
Data

- National Health and Nutrition Examination Survey (NHANES)
 - NHANES III (1988-1994), age 2-7 (N=5000)
 - NHANES 1999-2002, age 12-17 (N=3091)

For overweight adolescents:

- National Longitudinal Survey of Youth (NLSY):
 - age 2-4, 1990→age 12-14, overweight in 2000 (N=39)
- Bogalusa Heart Study:
 - age 5-7, 1981-2→age 16-18, overweight in 1992-3 (N=40)

Quantifying Excess Weight Gain during Growth

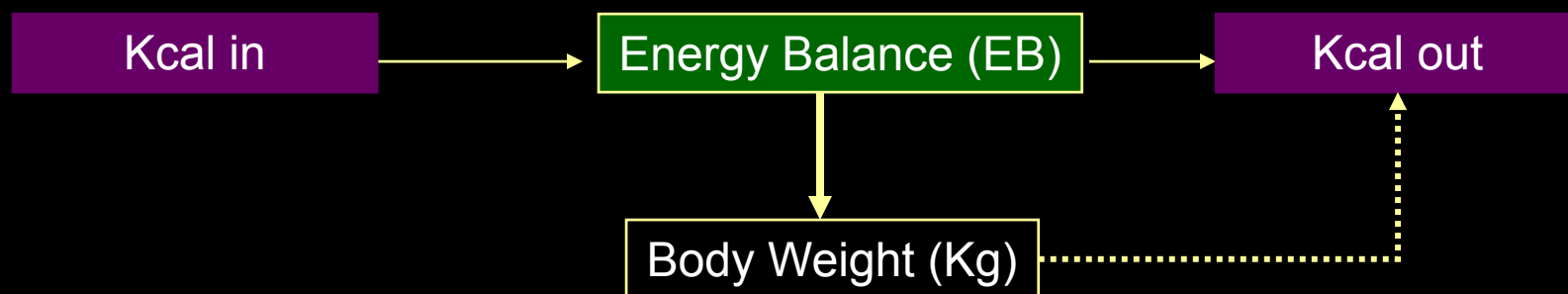


Reference: Wang YC, Gortmaker SL, Sobol AM, Kuntz KM. Pediatrics 2006. 118 (6): 1721-1733

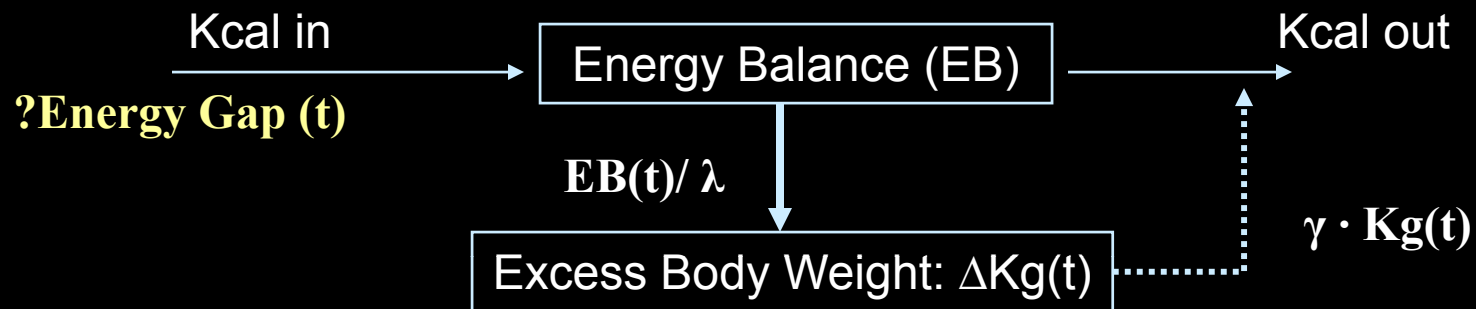
Translating Excess Weight Gain to Daily Energy Gap

■ Assumptions

- 3500 kcal accumulated = 1 lb weight gain as fat
- Efficiency of energy storage from food: 50-75%
- Linear accumulation of excess weight over 10 y
- Adjustment for higher energy expenditure following weight gain (differential equation)



Modeling the Nonlinear/Dynamic Process



Energy Gap (t) · e

= Deposit $\Delta extraKg(t)$ + Move $extraKg(t)$

= $\Delta extraKg(t) \cdot \lambda$ + $\Delta BMR(t) \cdot PAL$

Schofield Equation for boys 3-10y: $BMR(kcal/day) = 22.9 \cdot Weight^{0.734}$
 WHO values for 1. light 2. moderate activity levels, by age & sex

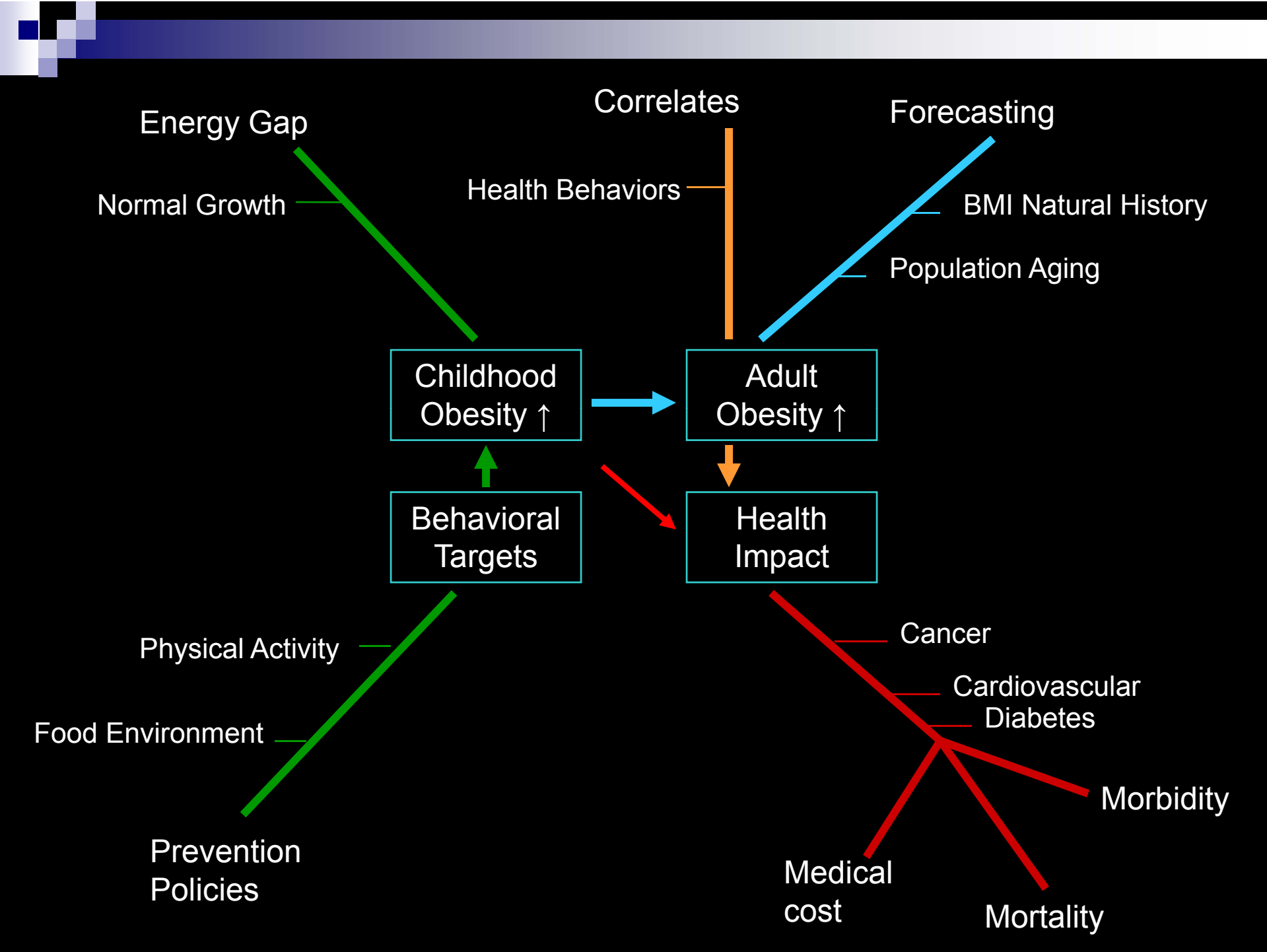
PAL: Physical Activity Level; BMR: Basal Metabolic Rate

Average Daily Energy Gap (kcal/day): 1988-94 to 1999-2002

| | <u>Excess Weight Gained (Lb)</u> | <u>Daily Energy Gap (kcal/day)</u> |
|------------------|--------------------------------------|--|
| All Teens | 10 | 110 -165 |
| Overweight Teens | 58 | 678 -1,017 |

- **Behavioral implications of 150 kcal/day for average kid:**
 - Replacing 1 can of soda (12 oz) with water (140 kcal)
 - Reducing TV watching by 1.4 hours/day (148 kcal)¹
 - Walking ~1.9 hours instead of sitting (150 kcal)
 - Increasing PE from 1 to 3 times/week (240 kcal-34/day)

¹Sonneville KR, Gortmaker SL. International Journal of Obesity, Int J Obes (Lond). 2008 Dec;32 Suppl 6:S19-27



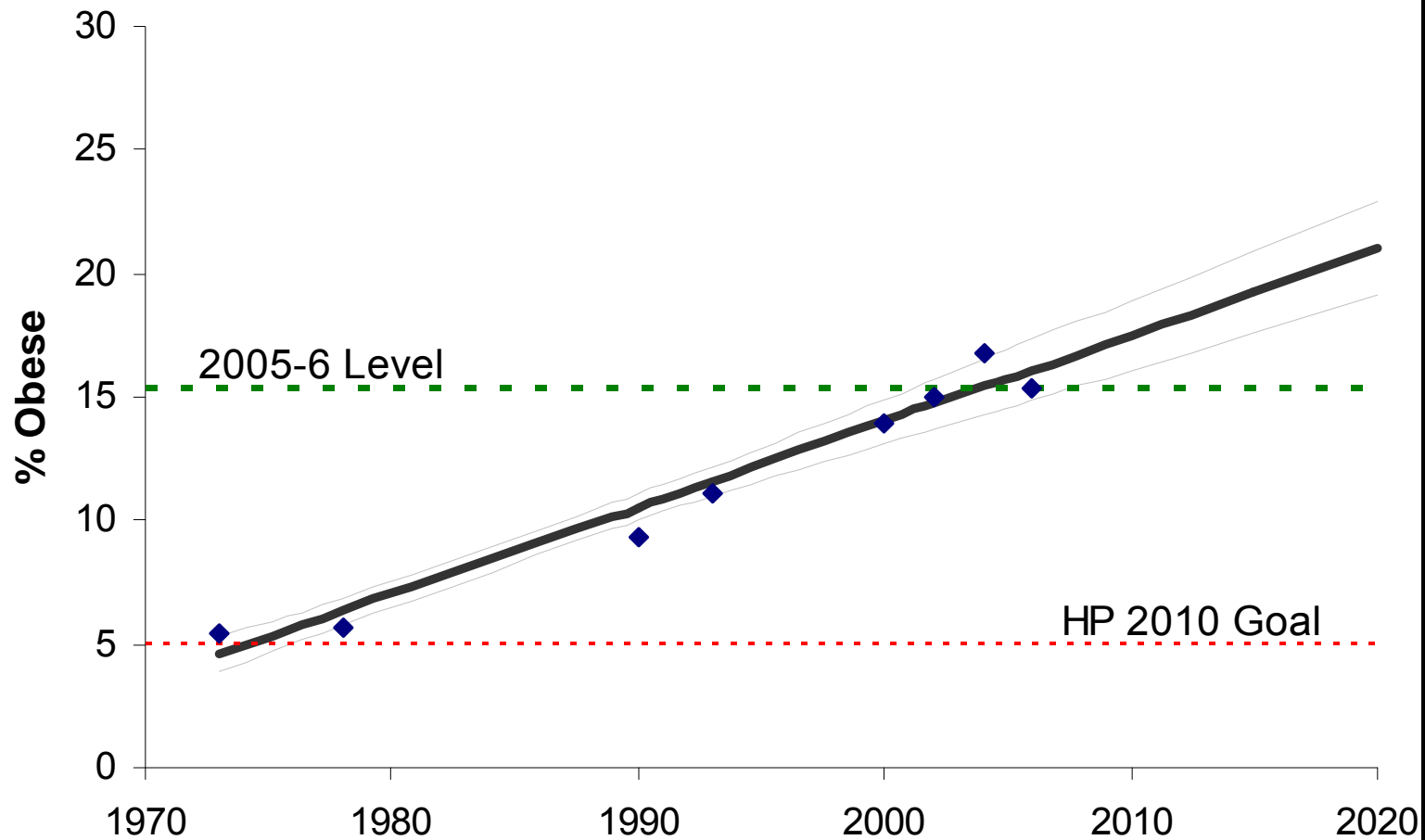


Applications of The Energy Gap Framework:

1. Forecasting:

Where will the epidemic take us and what should be done to reverse the trend?

Prevalence of Obesity, Age 2-19



Wang and Gortmaker. What Will It Take to Halt and Reverse Childhood Obesity Trends in the United States: Closing the Energy Gap and Disparities (In Progress)

Halting/Reversing the Trend

| Based on Trajectories of Mean Weight | | |
|--------------------------------------|----------------------|------------------------------------|
| AGE | To Flatten the Trend | To Reverse the Trend to 1970 Level |
| 2-19 | 43 (38-47) | 124 (96-152) |
| 2-5 | 9 (2-16) | 23 (13-34) |
| 6-11 | 42 (33-51) | 108 (72-143) |
| 12-19 | 56 (49-63) | 175 (128-220) |

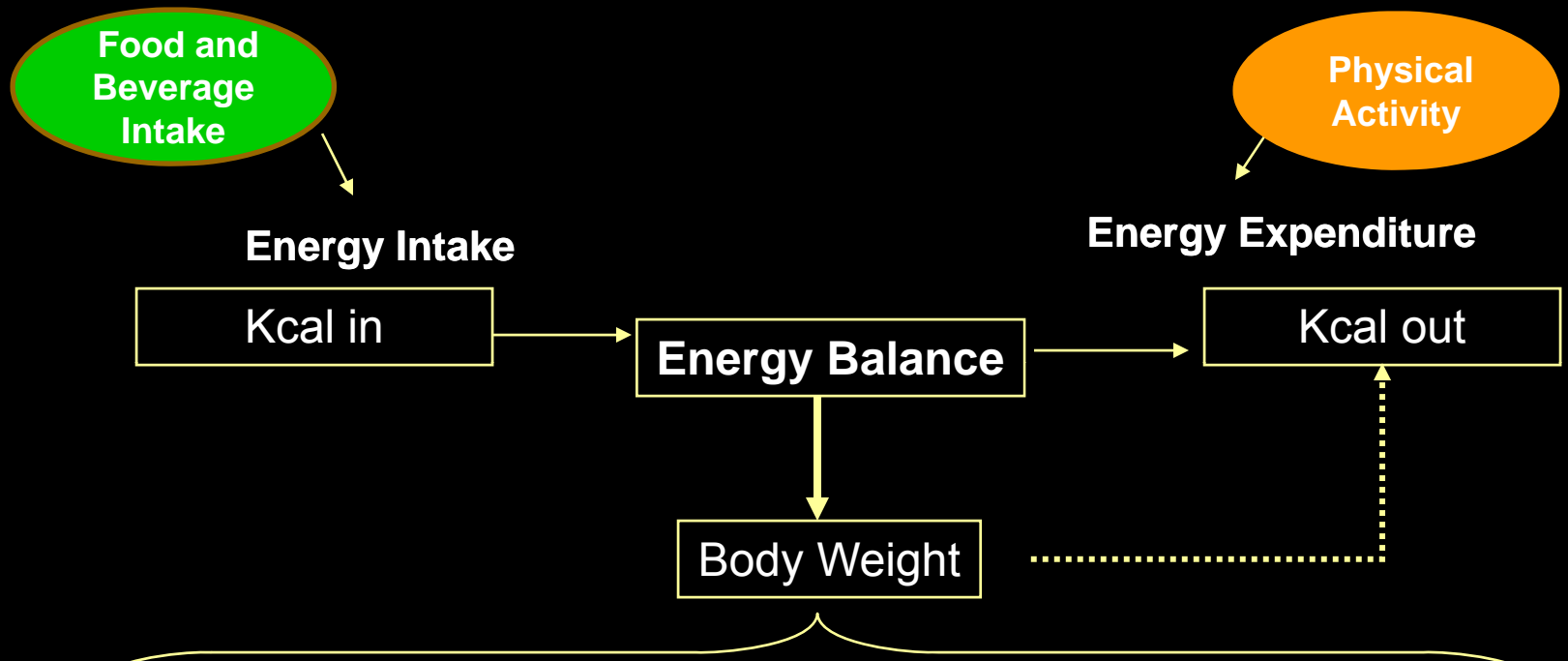
| Flattening Trajectories of Percentiles | | | |
|--|--------------|-----|-----|
| AGE | Median (P50) | P75 | P95 |
| 2-5 | 5 | 9 | 16 |
| 6-11 | 30 | 50 | 94 |
| 12-19 | 46 | 74 | 147 |



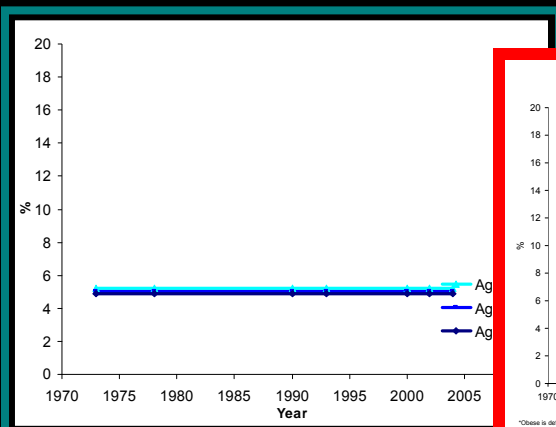
Applications of The Energy Gap Framework:

2. Population-based Simulation Model

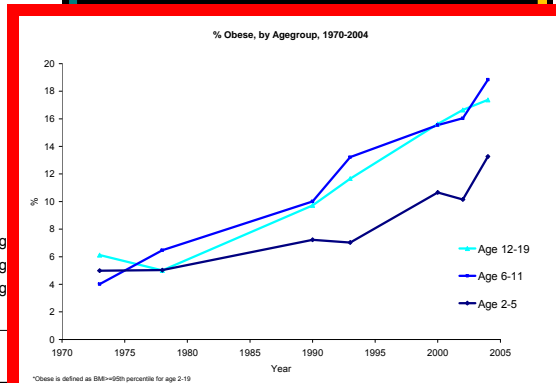
Energy Gap Simulation Model as a Policy Tool



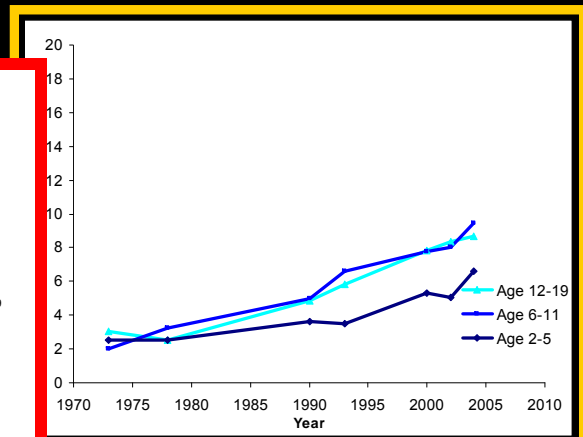
Ideal Scenario

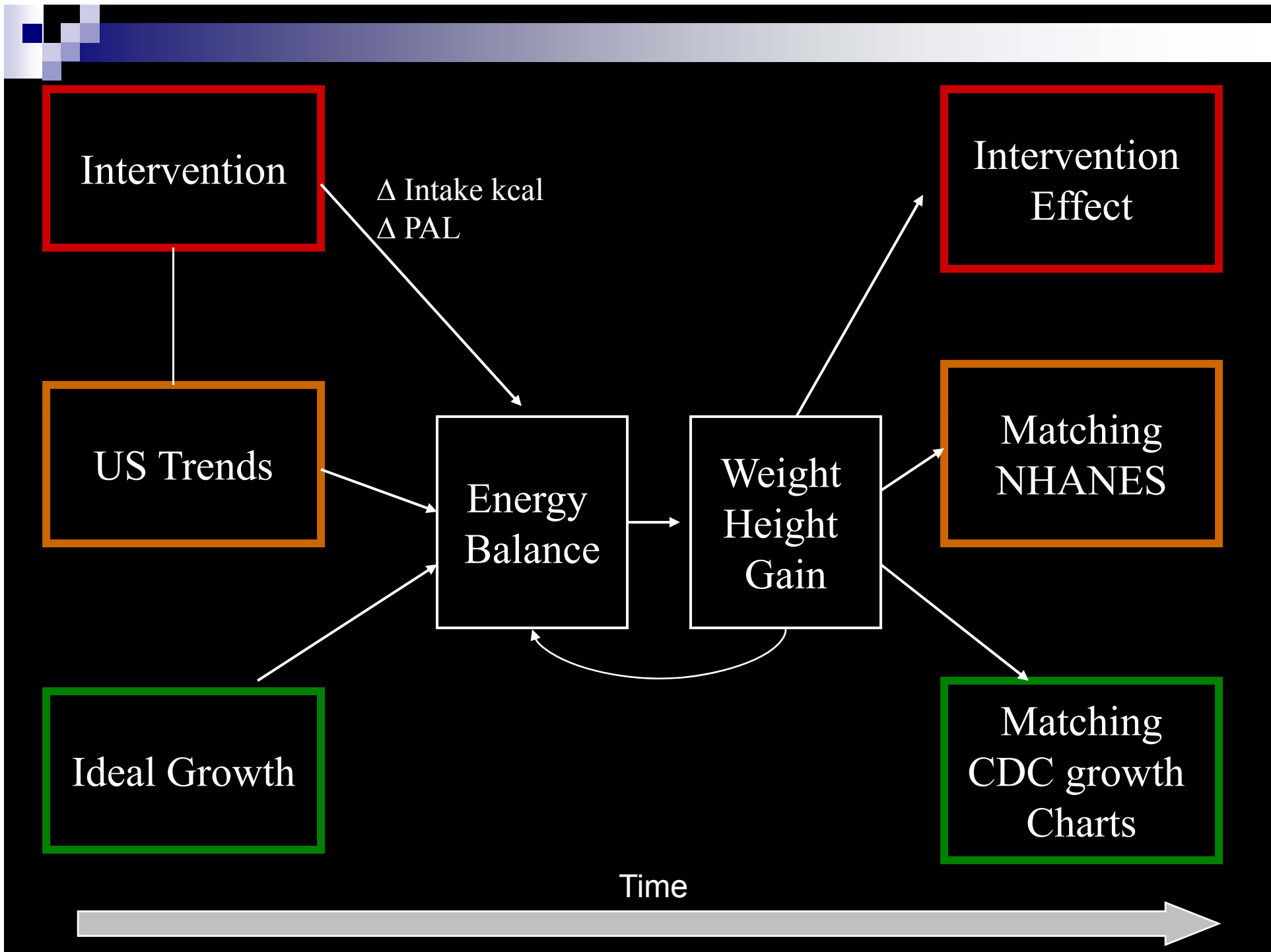


Observed Trend



Intervention Scenario





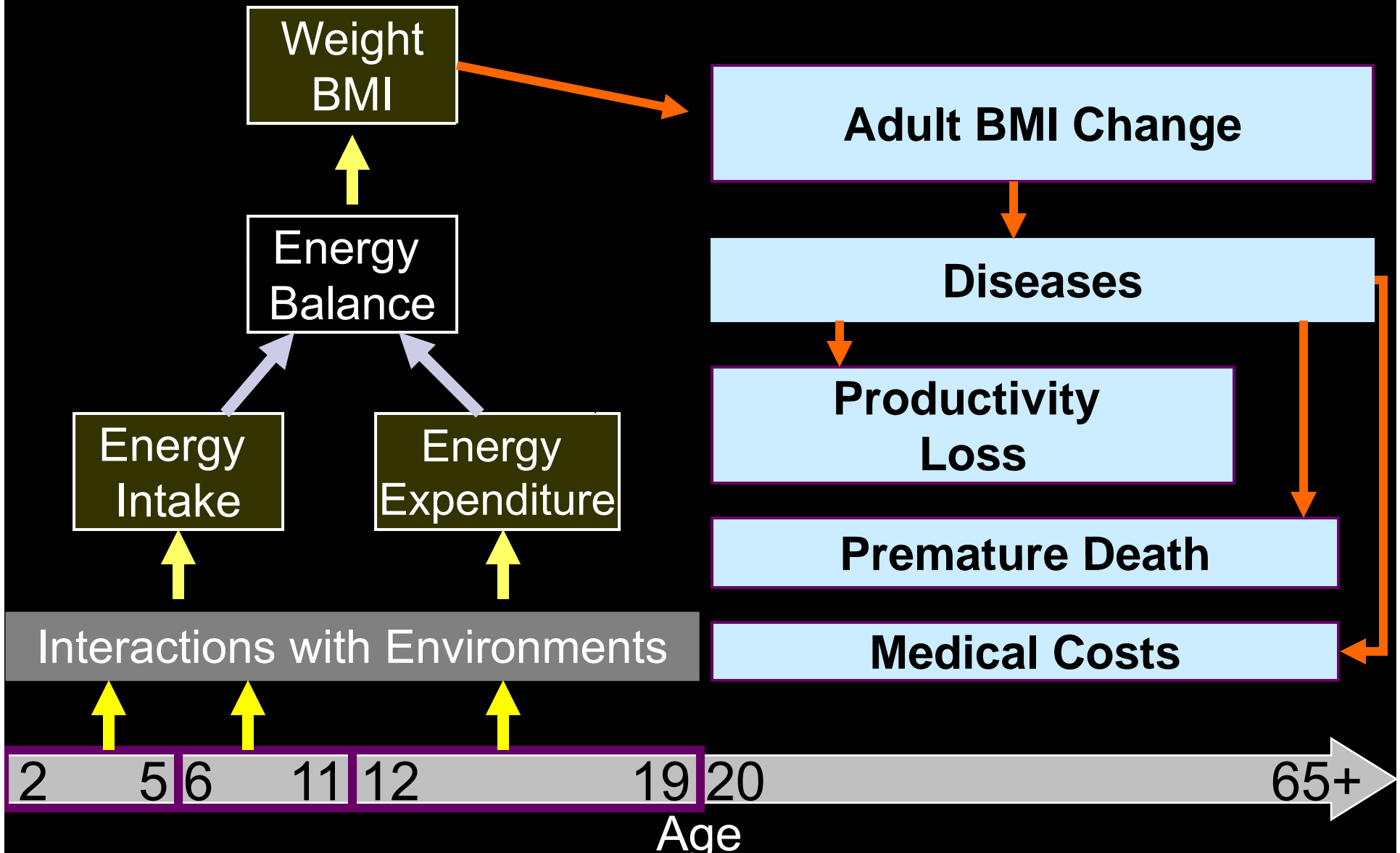
Model Structure

- Individual-based micro-simulation
- Initiate population: based on US census
- Assign body size change as a function of age
 - Ideal trajectory: wt_i, ht_i, BMI_i
 - Trend trajectory: $wt_T, ht_T=ht_i, BMI_T$
 - Intervention trajectory: $wt_v=wt_T-\Delta wt$
- Aggregate over all individual simulations
 - Percentiles (3, 5, 10, 15, 25, 50, 75, 85, 90, 95, 97)
 - % At-risk, % obese by age
- Disease outcomes: probabilistic process as a function of age, sex, BMI, race

Incorporating Multiple Data Sources

- Upstream causes:
 - Diet & activity trend
 - Effectiveness of interventions
 - Demographics
- Multiple consequences: cancer, cardiovascular diseases, diabetes, hypertension
 - Incidence, Relative Risk, Prevalence
 - Health outcomes and costs in the future

Model Structure



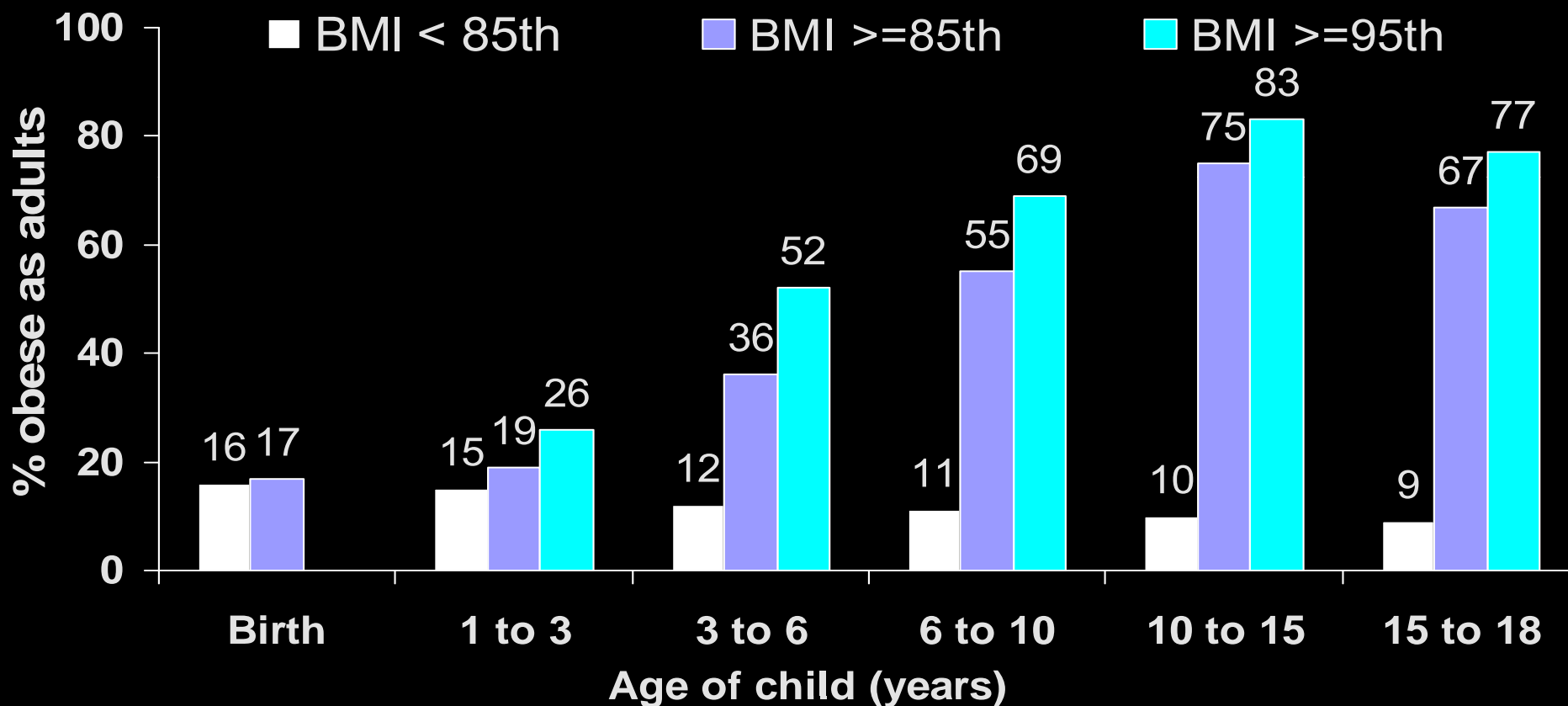
Why is the approach useful?

1. Taking a life-course approach
2. Incorporating demographic change
3. Accounting for the whole distribution and considering the nonlinear association with disease risks

1. A Life Course Perspective

- Children – Adolescents – Adult – Elderly
 - BMI tracks over time: obesity in childhood predict disease risks and persistence of obesity in adulthood.
 - Timing of obesity onset may be crucial, suggesting a critical period for prevention.

Tracking BMI-for-Age from Birth to 18 Years with % Overweight Children who Are Obese at Age 25

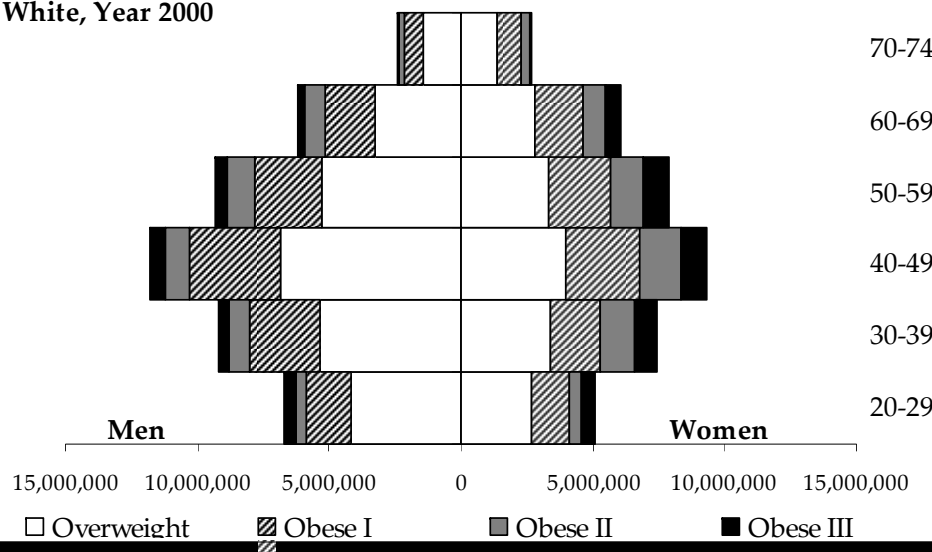


Source: Whitaker et al. NEJM 1997; 337: 869-873

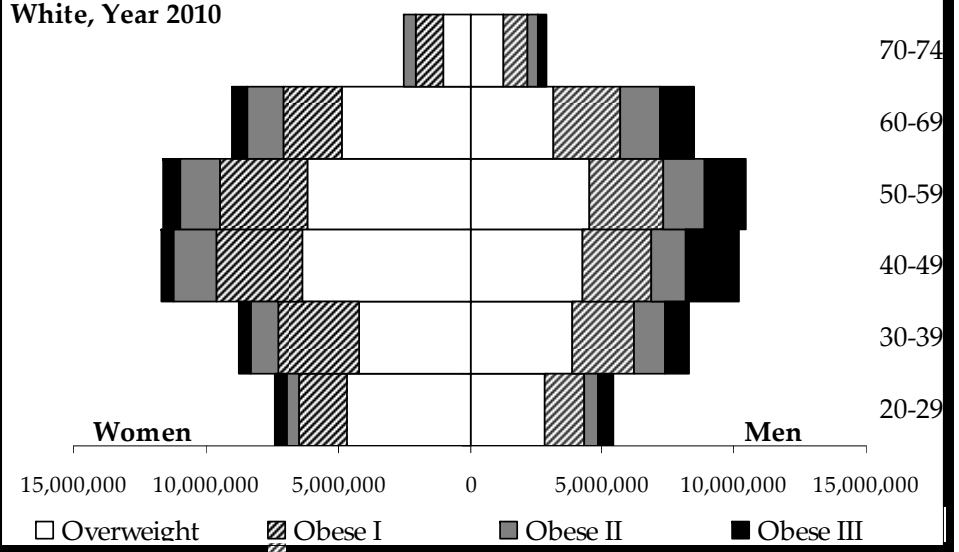
2. Incorporating demographic parameters

- Population aging
 - Obesity-related health risks and needs for health services depend on age
 - Implications on productivity
- Disparity in prevalence, diagnosis and treatment of downstream consequences leads to differences in expected costs of obesity
 - Race-ethnicity
 - Income and socio-economic status
 - Insurance status

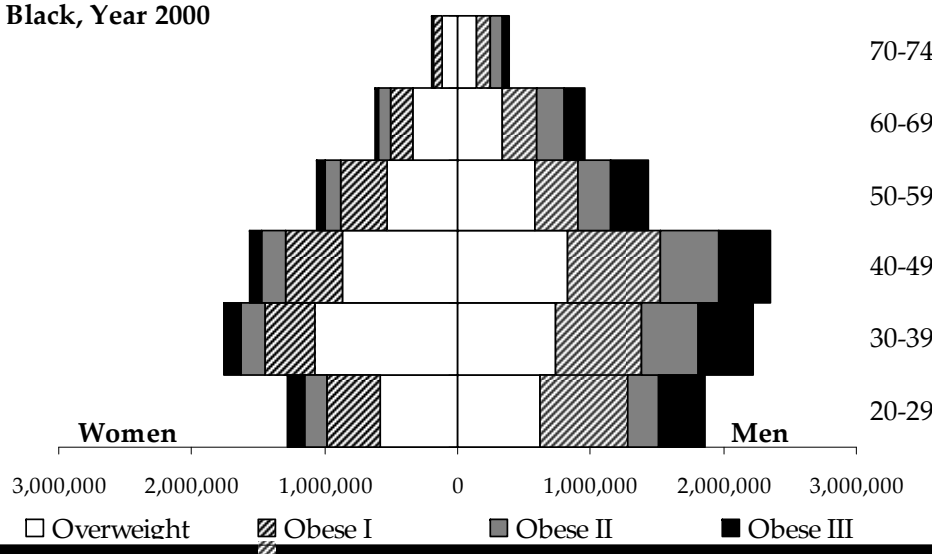
White, Year 2000



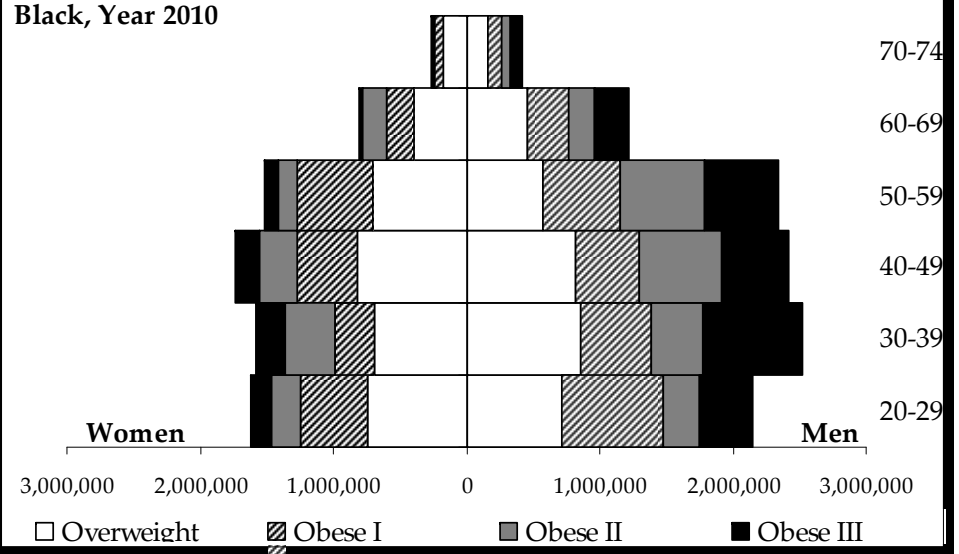
White, Year 2010



Black, Year 2000



Black, Year 2010



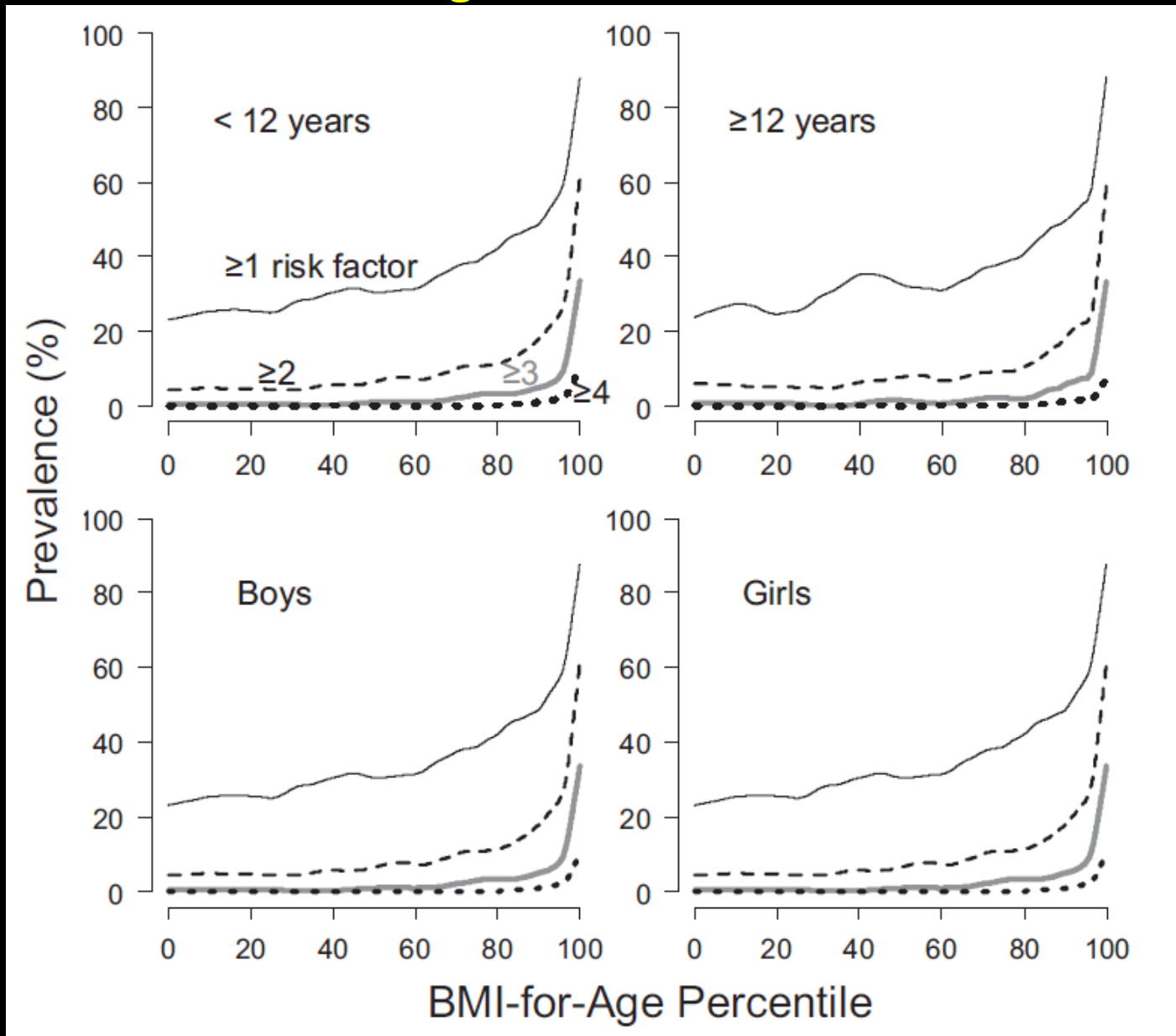
Reference: Wang 2007 Obesity 15(11) p2855-2865

Characterizing distributions of disease risks

-- Skewed Distribution --

- Disease risks and costs increase dramatically at very high BMI values ('tail' of distribution)
 - 'Non-linearity' of disease-BMI association
 - Estimating costs based on cutoffs of 'obese' or 'overweight' does not adequately capture the full burden of obesity, nor does it describe the real impact of reducing BMI among very obese individuals.
 - It is important to look at the entire BMI distribution, or at least the 'severely obese' population.

BMI-for-age and Disease Risks





Applications of The Energy Gap Framework:

3. Comparative effectiveness and cost-effectiveness of obesity prevention programs

Energy Gap as a Common Metric to Evaluate Interventions in Multiple Levels

- How to close the energy gap?
 - Caloric impact of policy/community initiatives:
 - Replacing sugar-sweetened beverages with water in schools: 12-31 kcal/day *
 - Sports, Play and Active Recreation for Kids (SPARK) fitness curriculum: ~35 kcal/day **
 - School beverage guideline (ABA/Clinton Foundation): 5-12 kcal/day ***
 - Caloric labeling? Tax on junk food?

* Based on data in: Wang YC, Bleich SN, Gortmaker SL. Pediatrics. 2008 Jun;121(6):e1604-14.

**Based on data in: Sallis JF, McKenzie TL, Alcaraz JE, Kolody B, Faucette N, Hovell MF. Am J Public Health. 1997 Aug;87(8):1328-34.

***Wang and Gortmaker, unpublished. Based on American Beverage Association: School beverage guideline progress report (2007-8)



Cost-effectiveness Evaluations as a Policy Tool

- What works better? What worth investing the resources more than others?
- Australian ACE-obesity team has shown what can be done beginning with a common metric and conducting additional cost and policy analysis
- Inform the set of “best bets” in childhood obesity prevention



All models are wrong, some are useful.

What is the right balance between reflecting complexity and policy relevance?

Discussions

1. What is the most policy-relevant way to model disparity?
2. What is the strategy to adapt the model to the changing epidemic?
3. What are the best data sources and approach to model cumulative exposure to obesity?



Acknowledgement

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