Health Canada and the Public Health Agency of Canada
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Estimation of Life Expectancy and Health-Adjusted Life Expectancy by BMI categories: a national population level approach

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Canada

Introduction

- Rates of overweight and obesity are increasing in Canada and other developed countries;
- Curbing obesity has become a long-term goal for public health professionals;
- Obesity is associated with premature mortality and loss in quality of life;
- Individuals with insufficient weight are also at risk for elevated morbidity and mortality;
- HALE can help to evaluate a combined effect on health and mortality associated with insufficient or excess weight.

Objectives

- Estimate and examine LE and HALE by Body Mass Index categories including two obesity sub-classes (class 1 and class 2+);
- Develop a methodology for LE and HALE estimation using available data;
- Estimate proportion of life spent in poor health;
- Evaluate contribution of HRQL and mortality to the loss of HALE ;
- Study population: Canadians 20 years old and over.

Data sources

- **National Population Health Survey**
  - Longitudinal survey (1994-2009, 8 cycles);
  - Household residents of all ages;
  - Initial sample size: 20,095. Response rate: 86%;
  - Study sample size:11,907 (Adults, 20+);
  - Mortality HR by BMI categories.
- **Canadian Community Health Survey**
  - Cross-sectional survey (started in 2000);
  - Household residents 12 years of age and over;
  - Sample size: 130,000. Response rate:91.9%-92.9% (2000-2005);
  - BMI prevalence.

Data sources

- **Canadian Chronic disease Surveillance System**
  - National collaborative framework of provincial and territorial surveillance systems supported by the Public Health Agency of Canada;
  - Covers almost the entire Canadian population: (individuals who have a valid publicly funded provincial or territorial health insurance;
  - Collect administrative data on mortality, chronic disease prevalence, incidence and health care utilization;
  - Covers period 1998-2009.

Mortality Rates by BMI categories

- **Partition of Total Mortality rates:**

$$R_j = R_t \left\{ \left(1 - \sum_{i \neq j}^{N} Q_i \right) + \sum_{i \neq j}^{N} RR_{ij} \, Q_i \right\}^{-1}$$

-mortality rates for normal weight category (reference)

$$R_i = RR_{ij} R_t \left\{ \left(1 - \sum_{i \neq j}^{N} Q_i \right) + \sum_{i \neq j}^{N} RR_{ij} \, Q_i \right\}^{-1}$$

-mortality rates other BMI categories

R_t -Total mortality rate
Q_i -BMI prevalence
RR_{ij}- Relative Risk of dying for *i*-category relatively to *j*-category

Period life table analysis

- **Chiang abridged life table**
  - Hsieh method to close life table (last age group: 85+)
- **Sullivan method to compute HALE**
  - Health Utilities Index Mark 3 (HUI) was used as a Measure of Health Related Quality of Life.
  - HUI weights quantify the proportion of full health for each year of life lived.
- **Bootstrap method to compute CI for LE and HALE**
- **SAS 9.3 used for calculations**

Health Utility Index Mark 3 (HUI)

- A multi-attribute health status classification system (a measure of health related quality of life).

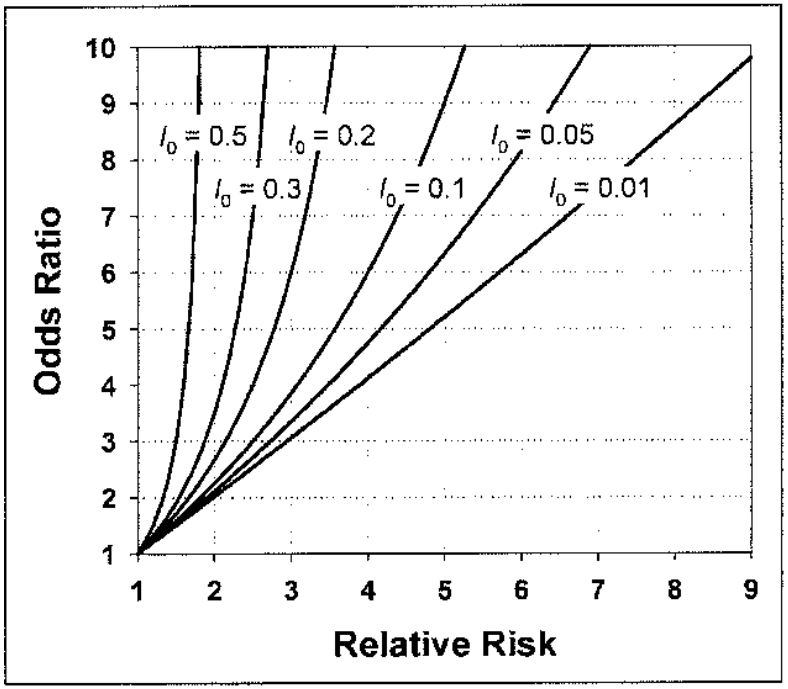
- Attributes (each having 5 or 6 levels to which weights are assigned by an expert panel):
  - Vision
  - Hearing
  - Speech
  - Ambulation
  - Dexterity
  - Emotion
  - Cognition
  - Pain

$$mHUI = 1.371 * \prod_{k=1}^{8} b_k - 0.371$$

$\boldsymbol{b_k}$-single attribute utility score

Mortality Relative Risk (RR)

- RR was approximated by hazard ratios (HR);
- HR is estimated from a discrete-time proportional hazard model (c-log-log link function).



- The model was adjusted by BMI category, sex and age group;
- Two age groups were used: 20-64,65+.

WHO BMI categories

BMI CATEGORY	
Underweight	BMI <18.5 kg/m^2
Normal weight	18.5 kg/m^2 ≤ BMI < 25 kg/m^2
Overweight	25 kg/m^2 ≤ BMI < 30 kg/m^2
Obesity I	30 kg/m^2 ≤ BMI < 35 kg/m^2
Obesity II+	BMI ≥ 35 kg/m^2

Self-reported BMI was used in the analysis (CCHS, NPHS).

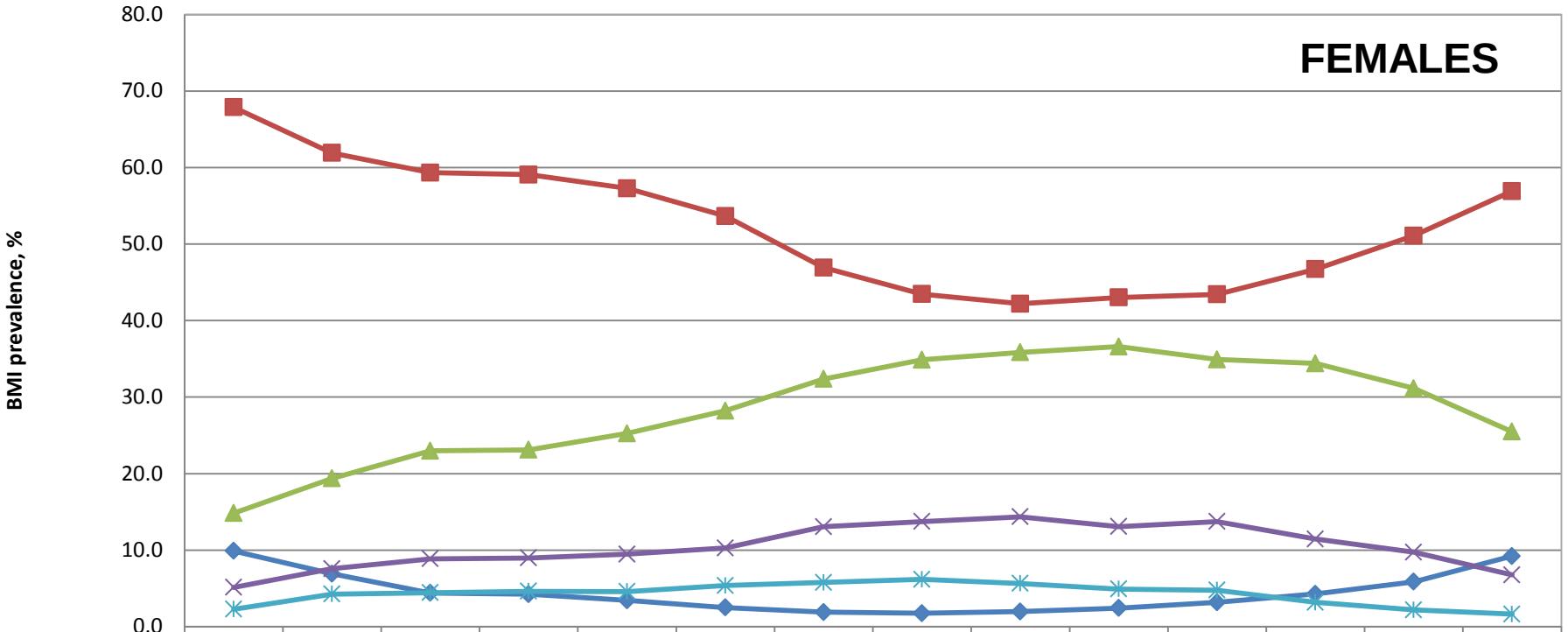
Sensitivity analysis: BMI corrected for self-report bias[1]

$BMI(adj) = -0.12 + 1.05 \times BMI(self\ reported)$ -FEMALES

$BMI(adj) = -1.08 + 1.08 \times BMI(self\ reported)$ -MALES

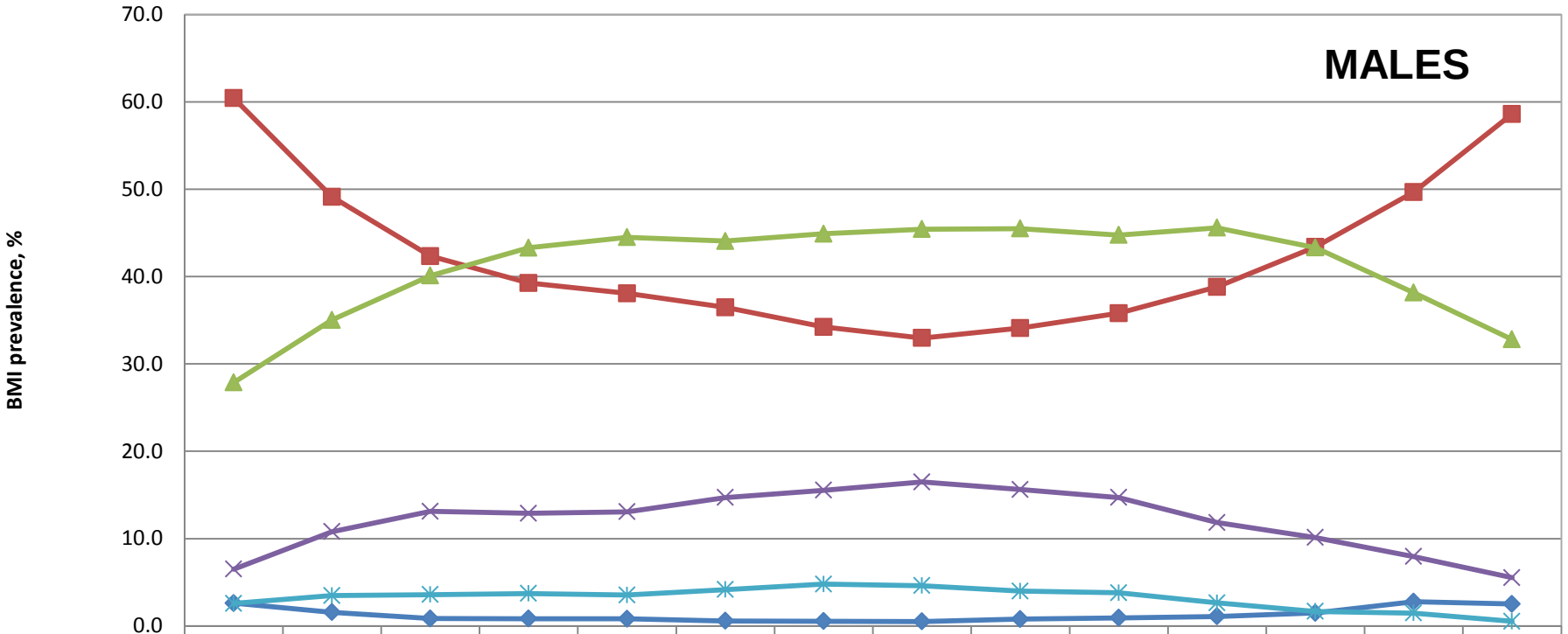
[1] Shields M, Connor Gorber S, Janssen I, Tremblay MS. Bias in self-reported estimates of obesity in Canadian health surveys: an update on correction equations for adults. *Health Rep* 2011;22(3).

BMI prevalence by category and age group



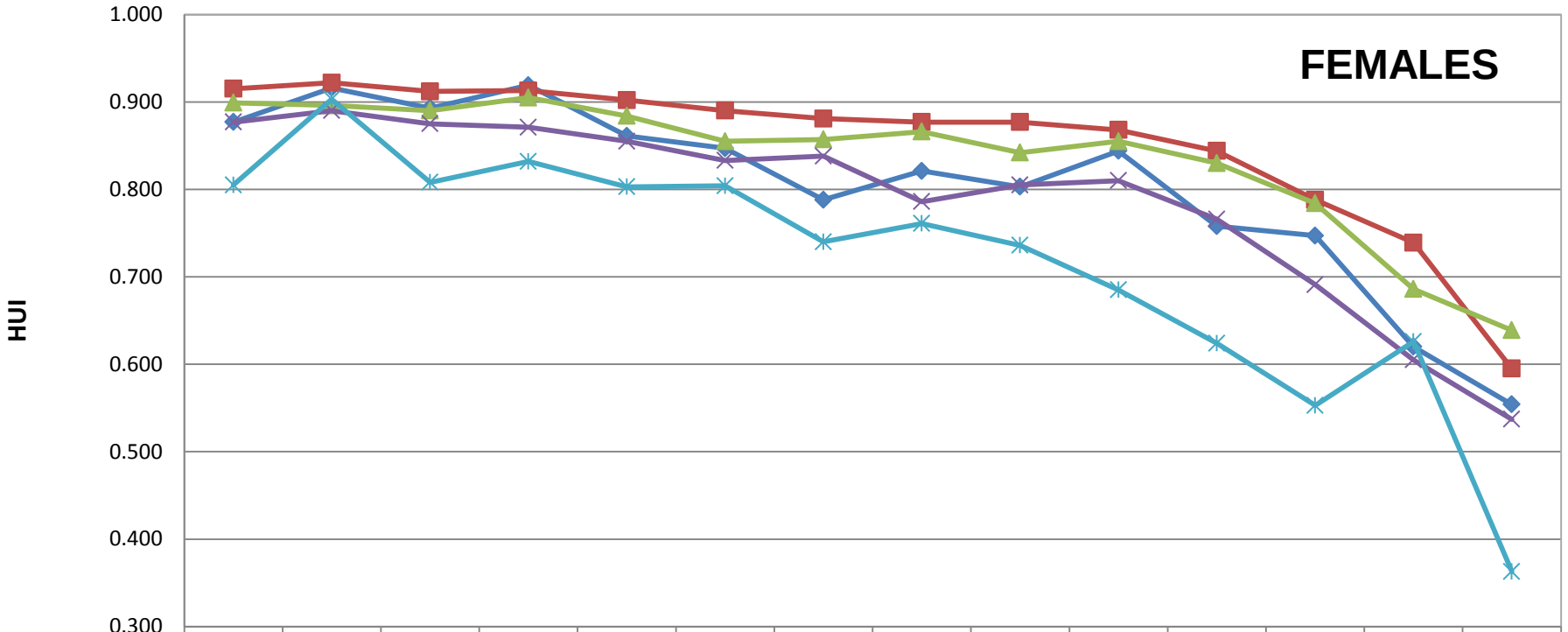
	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
Underwgt	9.9	6.9	4.4	4.2	3.4	2.5	1.9	1.7	2.0	2.4	3.2	4.3	5.9	9.2
Normal wgt	67.9	61.9	59.3	59.1	57.3	53.7	46.9	43.5	42.2	43.0	43.4	46.7	51.1	56.9
Overwgt	14.8	19.4	23.0	23.1	25.2	28.2	32.4	34.9	35.8	36.6	34.9	34.4	31.1	25.5
Obese I	5.1	7.6	8.9	9.0	9.5	10.3	13.1	13.7	14.4	13.1	13.7	11.5	9.7	6.8
Obese II+	2.3	4.2	4.4	4.6	4.6	5.4	5.8	6.2	5.6	4.9	4.8	3.2	2.2	1.6

BMI prevalence by category and age group



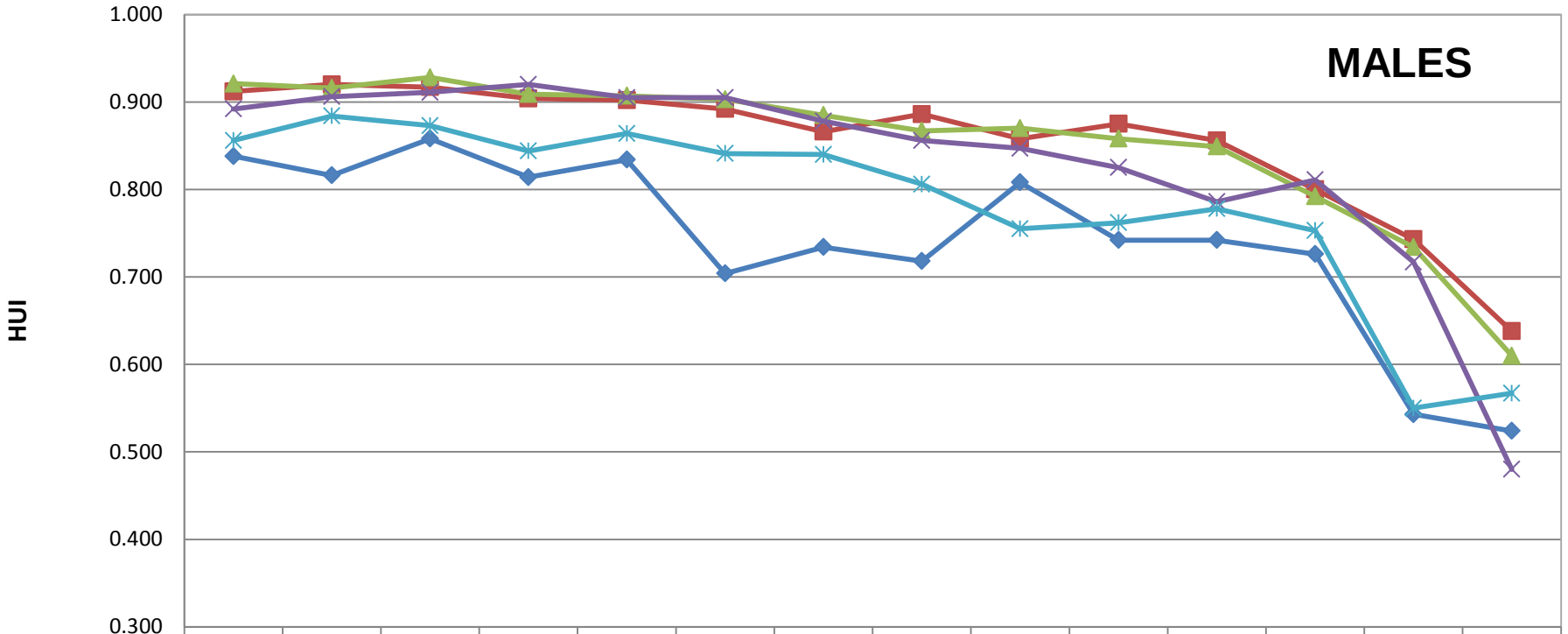
	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
Underwgt	2.6	1.6	0.9	0.8	0.8	0.6	0.5	0.5	0.8	0.9	1.1	1.5	2.8	2.5
Normal wgt	60.4	49.1	42.3	39.3	38.1	36.5	34.2	33.0	34.1	35.8	38.8	43.4	49.7	58.6
Overwgt	27.9	35.0	40.1	43.3	44.5	44.1	44.9	45.4	45.5	44.8	45.6	43.3	38.1	32.8
Obese I	6.5	10.8	13.1	12.9	13.1	14.7	15.5	16.5	15.6	14.7	11.8	10.1	7.9	5.5
Obese II+	2.6	3.5	3.6	3.7	3.5	4.2	4.8	4.6	4.0	3.8	2.7	1.7	1.5	0.5

HUI by BMI category and age group



	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
Underwgt	0.877	0.916	0.893	0.919	0.861	0.847	0.788	0.821	0.803	0.844	0.758	0.747	0.620	0.554
Normal wgt	0.915	0.922	0.912	0.913	0.902	0.890	0.881	0.877	0.877	0.868	0.844	0.788	0.739	0.595
Overwgt	0.899	0.896	0.890	0.905	0.884	0.855	0.857	0.866	0.842	0.855	0.830	0.784	0.686	0.639
Obese I	0.877	0.890	0.875	0.871	0.855	0.833	0.838	0.786	0.805	0.810	0.766	0.691	0.605	0.537
Obese II+	0.805	0.903	0.808	0.832	0.803	0.804	0.740	0.761	0.736	0.685	0.624	0.553	0.626	0.363

HUI by BMI category and age group



	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85+
Underwgt	0.838	0.816	0.858	0.814	0.834	0.704	0.734	0.718	0.808	0.742	0.742	0.726	0.543	0.524
Normal wgt	0.912	0.920	0.917	0.904	0.902	0.892	0.866	0.886	0.858	0.875	0.856	0.800	0.743	0.638
Overwgt	0.921	0.916	0.928	0.909	0.907	0.903	0.885	0.867	0.870	0.858	0.849	0.792	0.734	0.610
Obese I	0.892	0.906	0.911	0.920	0.905	0.905	0.878	0.856	0.847	0.825	0.786	0.811	0.717	0.480
Obese II+	0.856	0.884	0.873	0.844	0.864	0.841	0.840	0.806	0.755	0.762	0.778	0.753	0.550	0.567

Hazard ratios (HR)

Model: a discrete-time proportional hazard model with c-log-log link was adjusted by sex, BMI categories and age group.

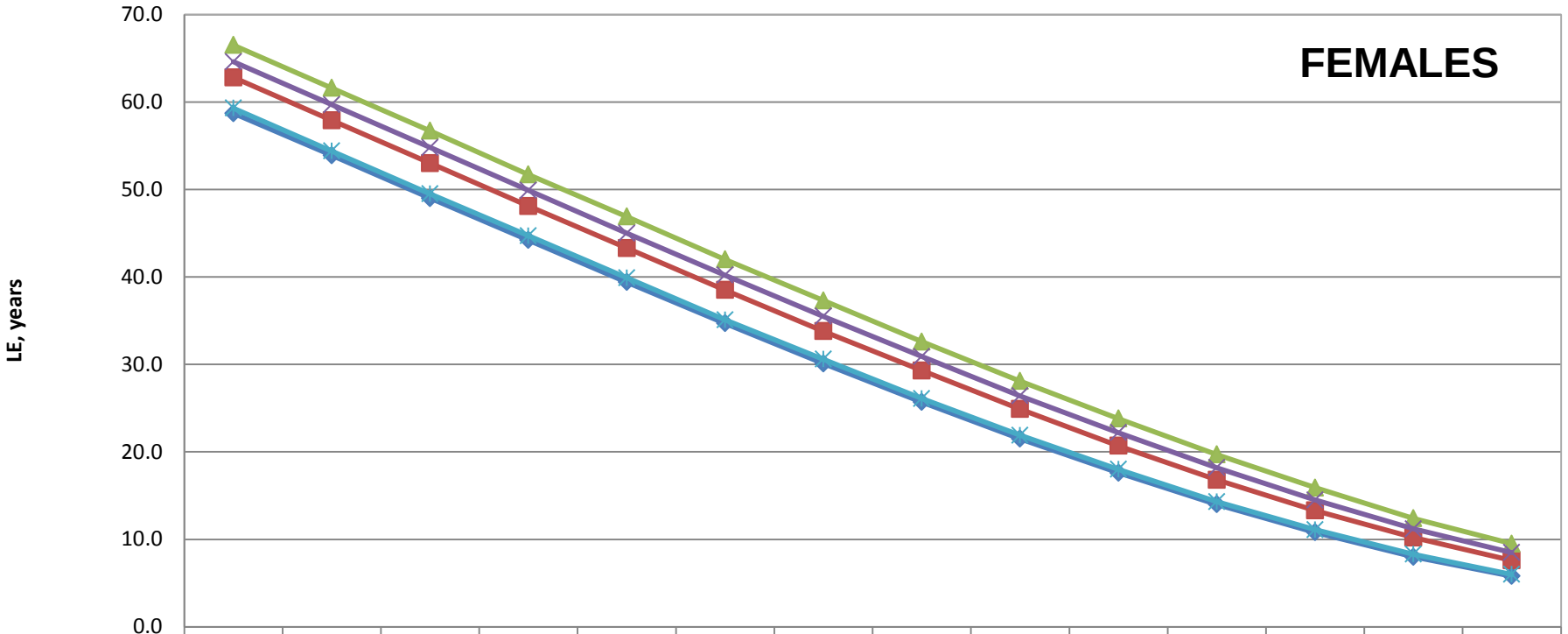
BMI CATEGORY	HR	95 % LOWER LIMIT	95 % UPPER LIMIT	P-value
Underweight	1.49	1.17	1.9	<0.01
Normal weight	1			
Overweight	0.69	0.62	0.78	<0.0001
Obesity I	0.84	0.72	0.98	<0.05
Obesity II+	1.42	1.16	1.72	<0.001

Sensitivity analysis

Model: a discrete-time proportional hazard model with c-log-log link was adjusted by sex, BMI categories, age group and smoking.

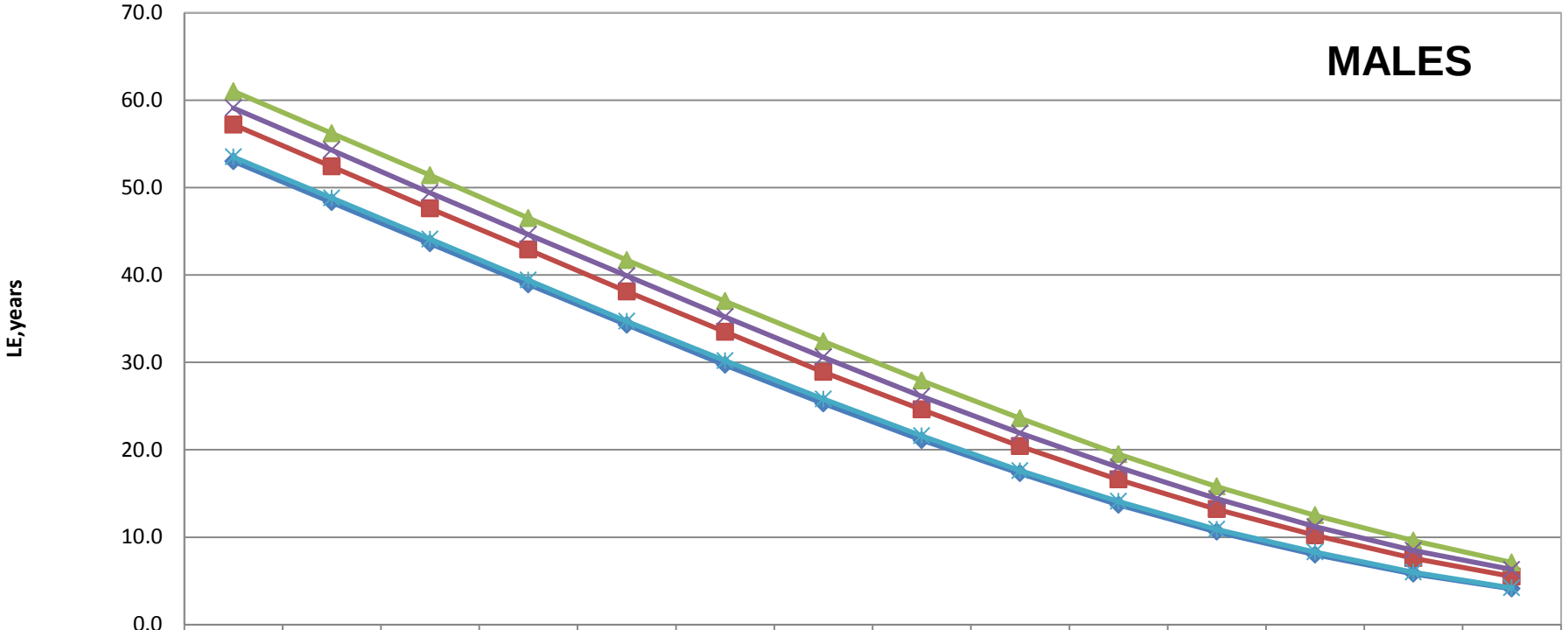
HR were not significantly different

Life Expectancy by BMI category



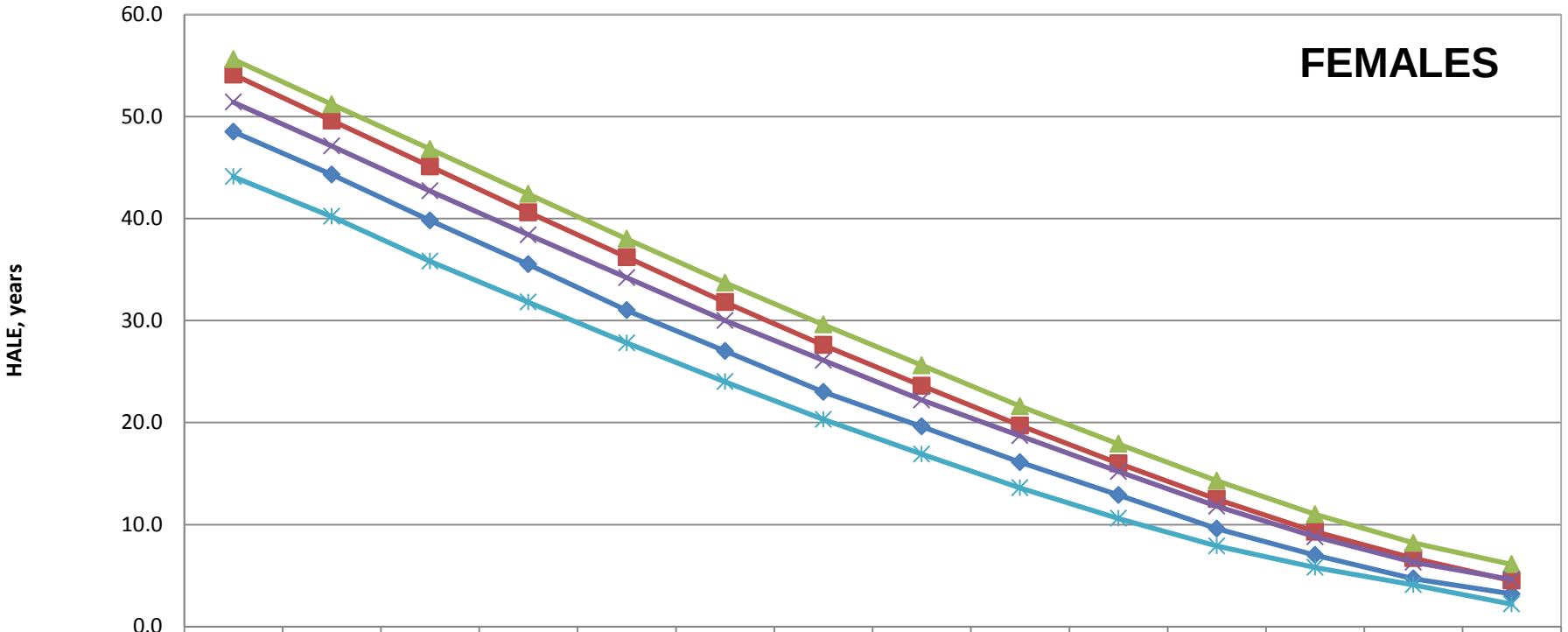
	20	25	30	35	40	45	50	55	60	65	70	75	80	85+
Underwgt	58.7	53.9	49.0	44.2	39.4	34.7	30.1	25.7	21.5	17.6	14.0	10.8	8.0	5.8
Normal wgt	62.8	57.9	53.0	48.1	43.3	38.5	33.8	29.3	24.9	20.7	16.8	13.3	10.2	7.6
Overwgt	66.5	61.6	56.7	51.7	46.9	42.0	37.3	32.6	28.1	23.8	19.7	15.9	12.4	9.5
Obese I	64.6	59.7	54.8	49.9	45.0	40.2	35.5	30.9	26.4	22.2	18.2	14.5	11.2	8.5
Obese II+	59.3	54.4	49.5	44.7	39.9	35.1	30.6	26.1	21.9	18.0	14.3	11.1	8.3	6.0

Life Expectancy by BMI category



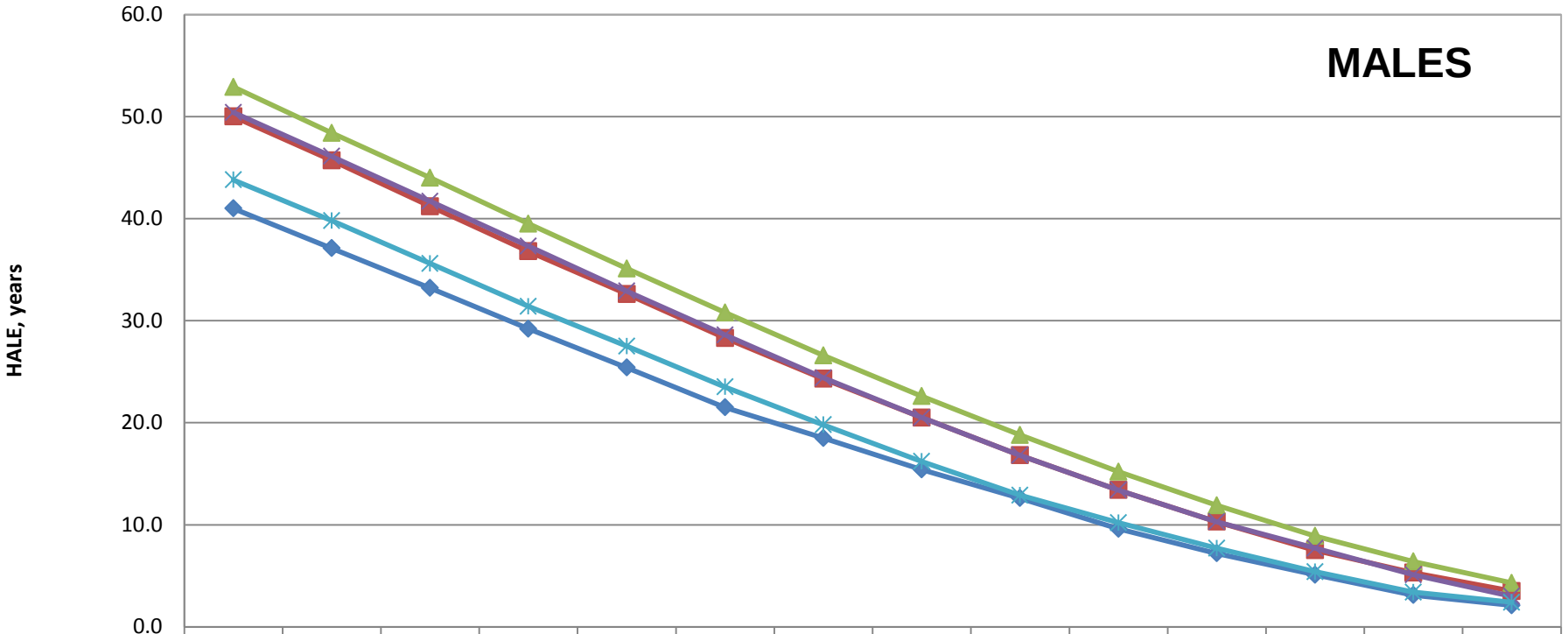
	20	25	30	35	40	45	50	55	60	65	70	75	80	85+
Underwgt	53.0	48.3	43.6	38.9	34.3	29.7	25.3	21.1	17.3	13.7	10.6	8.0	5.8	4.1
Normal wgt	57.2	52.4	47.6	42.9	38.1	33.5	28.9	24.6	20.4	16.6	13.2	10.2	7.6	5.5
Overwgt	61.0	56.2	51.4	46.5	41.7	37.0	32.4	27.9	23.6	19.5	15.8	12.5	9.6	7.1
Obese I	59.1	54.3	49.4	44.6	39.9	35.2	30.6	26.1	21.9	18.0	14.4	11.2	8.5	6.3
Obese II+	53.5	48.8	44.1	39.4	34.7	30.2	25.8	21.6	17.6	14.1	10.9	8.3	6.0	4.2

Health-Adjusted Life Expectancy by BMI category



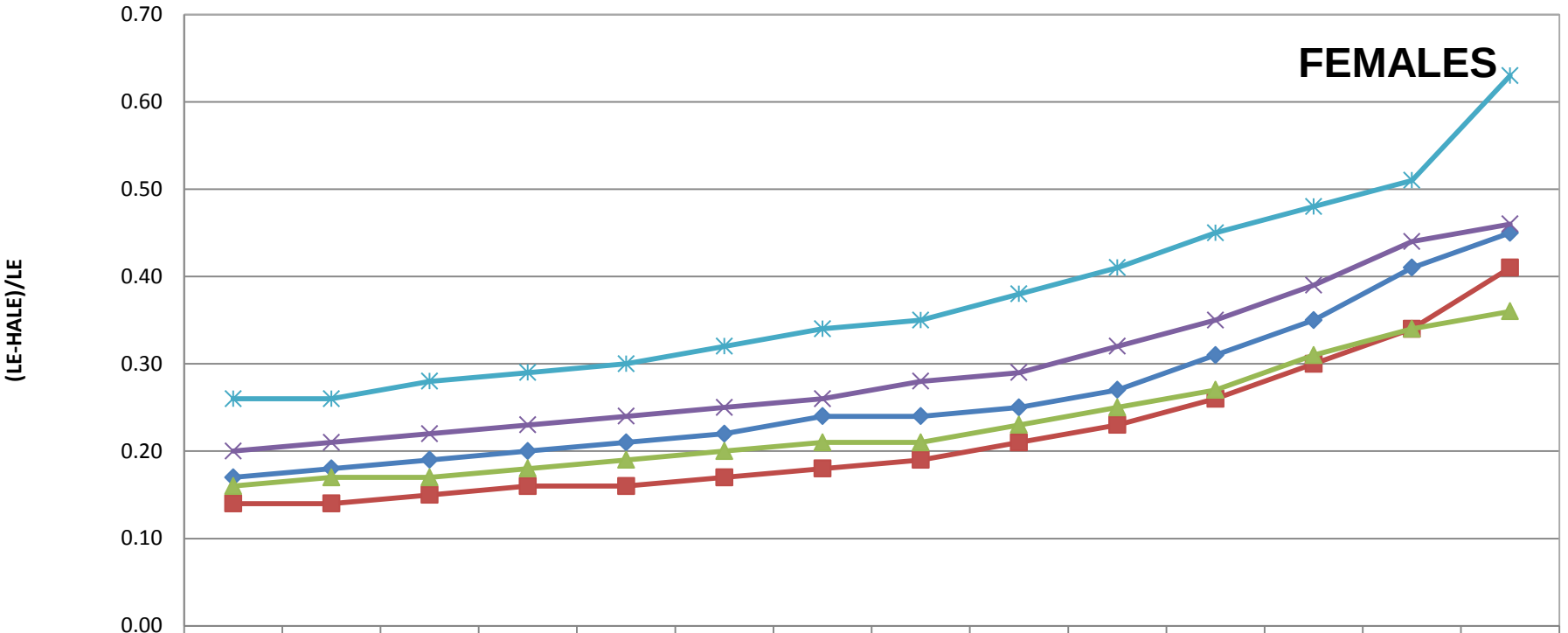
	20	25	30	35	40	45	50	55	60	65	70	75	80	85+
Underwgt	48.5	44.3	39.8	35.5	31.0	27.0	23.0	19.6	16.1	12.9	9.6	7.0	4.7	3.2
Normal wgt	54.1	49.6	45.1	40.6	36.2	31.8	27.6	23.6	19.7	16.0	12.5	9.3	6.7	4.5
Overwgt	55.6	51.2	46.8	42.4	38.0	33.7	29.6	25.6	21.6	17.9	14.3	11.0	8.2	6.1
Obese I	51.4	47.1	42.7	38.4	34.2	30.0	26.1	22.2	18.7	15.2	11.8	8.8	6.3	4.6
Obese II+	44.1	40.2	35.8	31.8	27.8	24.0	20.3	16.9	13.6	10.6	7.9	5.8	4.1	2.2

Health-Adjusted Life Expectancy by BMI category



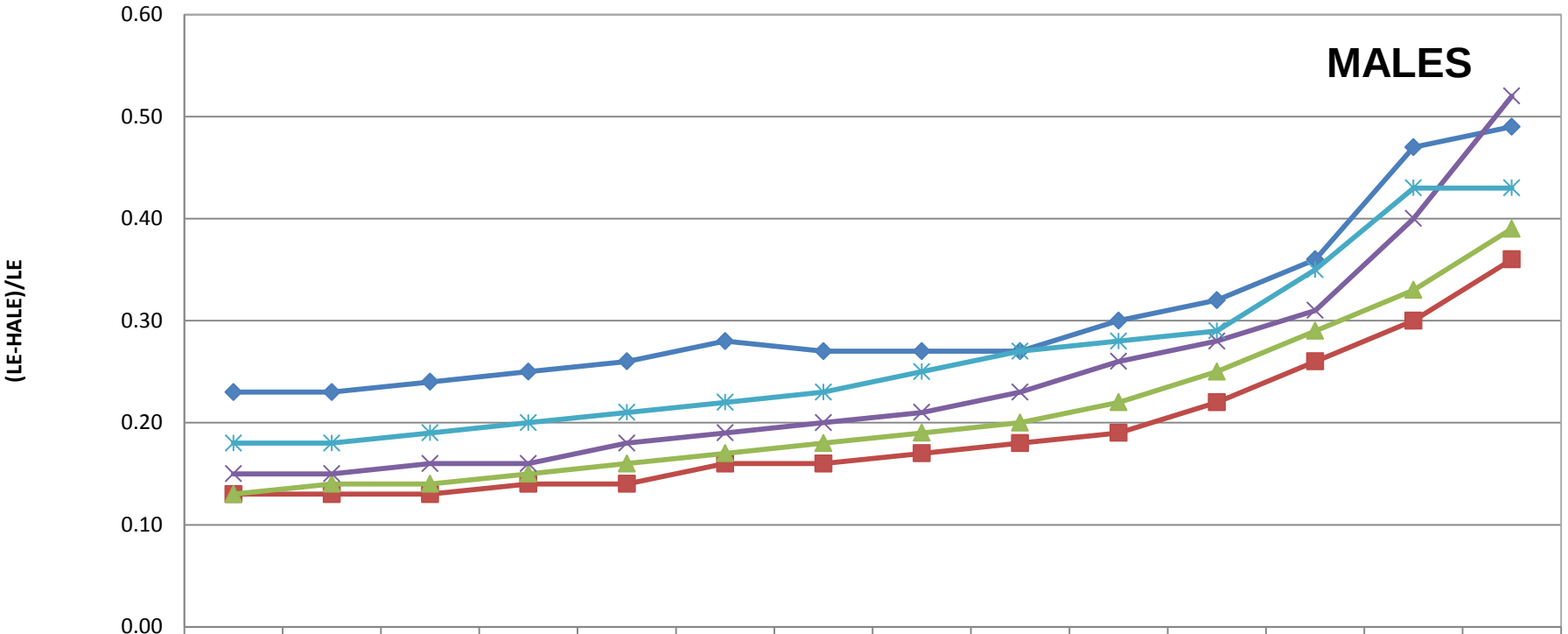
	20	25	30	35	40	45	50	55	60	65	70	75	80	85+
Underwgt	41.0	37.1	33.2	29.2	25.4	21.5	18.5	15.4	12.6	9.6	7.2	5.1	3.1	2.1
Normal wgt	50.0	45.7	41.2	36.8	32.6	28.3	24.3	20.5	16.8	13.4	10.3	7.5	5.3	3.5
Overwgt	52.9	48.4	44.0	39.5	35.1	30.8	26.6	22.6	18.8	15.2	11.9	8.9	6.4	4.3
Obese I	50.4	46.1	41.7	37.3	32.9	28.6	24.4	20.5	16.8	13.4	10.3	7.7	5.1	3.0
Obese II+	43.8	39.8	35.6	31.4	27.5	23.5	19.8	16.2	12.9	10.2	7.7	5.4	3.4	2.4

Proportion of life spent in poor health



	20	25	30	35	40	45	50	55	60	65	70	75	80	85+
Underwgt	0.17	0.18	0.19	0.20	0.21	0.22	0.24	0.24	0.25	0.27	0.31	0.35	0.41	0.45
Normal wgt	0.14	0.14	0.15	0.16	0.16	0.17	0.18	0.19	0.21	0.23	0.26	0.30	0.34	0.41
Overwgt	0.16	0.17	0.17	0.18	0.19	0.2	0.21	0.21	0.23	0.25	0.27	0.31	0.34	0.36
Obese I	0.20	0.21	0.22	0.23	0.24	0.25	0.26	0.28	0.29	0.32	0.35	0.39	0.44	0.46
Obese II	0.26	0.26	0.28	0.29	0.30	0.32	0.34	0.35	0.38	0.41	0.45	0.48	0.51	0.63

Proportion of life spent in poor health



	20	25	30	35	40	45	50	55	60	65	70	75	80	85+
Underwgt	0.23	0.23	0.24	0.25	0.26	0.28	0.27	0.27	0.27	0.30	0.32	0.36	0.47	0.49
Normal wgt	0.13	0.13	0.13	0.14	0.14	0.16	0.16	0.17	0.18	0.19	0.22	0.26	0.30	0.36
Overwgt	0.13	0.14	0.14	0.15	0.16	0.17	0.18	0.19	0.2	0.22	0.25	0.29	0.33	0.39
Obese I	0.15	0.15	0.16	0.16	0.18	0.19	0.20	0.21	0.23	0.26	0.28	0.31	0.40	0.52
Obese II	0.18	0.18	0.19	0.20	0.21	0.22	0.23	0.25	0.27	0.28	0.29	0.35	0.43	0.43

LE, HALE and differences in LE and HALE at age 20 by BMI category and sex

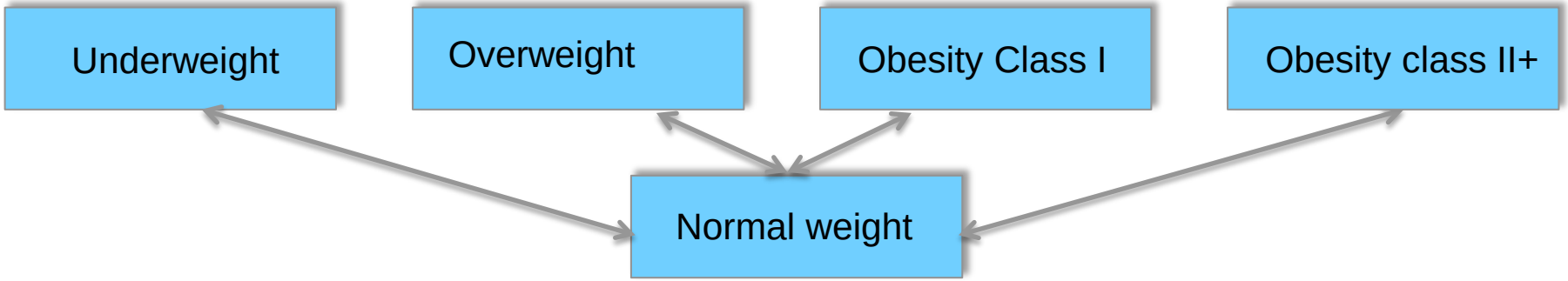
	Underweight	Normal weight	Overweight	Obesity Class I	Obesity Class II+
FEMALES					
LE	58.7	62.8	66.5	64.6	59.3
HALE	48.5	54.1	55.6	51.4	44.1
LE-HALE	10.2*	8.7	10.9*	13.2*	15.2*
(LE-HALE)/LE	0.174	0.139	0.164	0.204	0.256
MALES					
LE	53.0	57.2	61.0	59.1	53.5
HALE	41.0	50.0	52.9	50.4	43.8
LE-HALE	12.0*	7.2	8.1*	8.7	9.7*
(LE-HALE)/LE	0.226	0.126	0.133	0.147	0.181

* Statistically significant difference vs. normal weight ($p<0.01$

Decomposition of HALE difference

$$\Delta HALE = HALE_i - HALE_j$$

j- Normal weight category (reference)



$$\Delta HALE = \Delta MORT + \Delta MORB$$

$$\Delta HALE = \frac{L_{x1} + L_{x2}}{2} \times \Delta HUI_x + \frac{HUI_{x1} + HUI_{x2}}{2} \times \Delta L_x$$

Decomposition of HALE difference at age 20

	FEMALES					MALES				
	UW	NW	OV	OB I	OB II+	UW	NW	OV	OB I	OB II+
$\Delta HALE$	-5.6*	REF	1.5*	-2.7*	-10.0*	-9.0*	REF	2.9*	0.4	-6.2*
$\Delta MORT$	-2.8	REF	2.6	1.2	-2.2	-3.0	REF	2.9	1.3	-2.7
$\Delta MORB$	-2.7	REF	-1.0	-3.8	-7.8	-5.9	REF	0.0	-1.0	-3.5

* Statistically significant difference, p<0.01

Some discrepancies in $\Delta HALE$ and decomposition components are due to rounding

Strength and limitations

- The methodology of total mortality rates partitioned by N categories can be used for LE and HALE estimation by disease, risk factors and SES provided that RR and prevalence are available;
- It gives similar results when compared with more complicated methods (e.g. probabilistic linkage);
- The study reports LE and HALE by obesity sub-categories and demonstrates important differences.

Strength and limitations

- BMI prevalence and HR were estimated for household population only;
- Self-reported BMI was used;
- Baseline BMI (1994) were used for HR estimation. BMI changes over time were not accounted;
- NPHS had a small sample size and a short follow-up period;
- Other measures of body weight (e.g. waist circumference, skinfold thickness, waist-to-heights ratio) were not used. They might provide more accurate measurements of adiposity.

Conclusions

The study:

- Indicates that there are important LE and HALE differences between BMI categories and by sex;
- Demonstrates significant loses in LE and HALE in the underweight and higher obesity classes and significant gains in LE and HALE in the overweight category compared to normal weight category;
- Illustrates progressive increase in the loss of HALE due to loss in HRQL as BMI increases beyond normal weight;
- Reveal that the gain in HALE for overweight individuals are accounted by the contribution of reduced mortality.

THANK YOU!

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Questions…….