Life Course Weight Measurements and Cardiovascular Biomarkers in Persons Age 60 and Older: a Comparison of the United States and Costa Rica

David H. Rehkopf, Stanford University, Department of Medicine

William H. Dow, University of California, Berkeley, School of Public Health

Luis Rosero-Bixby, Universidad de Costa Rica, Centro Centroamericano de Poblacion

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The CRELES project (Costa Rica: study of longevity and healthy aging) is a longitudinal study of the *Universidad de Costa Rica*, carried on by the *Centro Centroamericano de Población* in collaboration with the *Instituto de Investigaciones en Salud*, with the support of the Wellcome Trust Foundation (grant N. 072406).

Background

Body weight is currently understood to be one of the major drivers of population health. The rapid increases in body weight have developed to be one of the greatest current medical and public health concerns (Flegal 2010), taking a backseat to only tobacco use as an epidemic in developed and developing countries. Increases in body weight have been suggested to have the potential to reverse the steady decreases in mortality that have occured in developed countries in the latter half of the 20th century. Despite a tremendous research effort, substantial questions still remain about when, where and how obesity matters as a driver of mortality. The majority of studies have been done in developed countries, and have most frequently used only single measurements of obesity (measured as BMI) that are taken in middle to later life. The majority of these studies have shown the commonly understood non-linear increased hazard of mortality with particularly increased mortality occuring over a BMI of 35.

Our current analysis addresses three methodological and substantive questions that build on the current evidence base. First, is current BMI the best predictor of mortality risk, or is weight early in life (at age 25), or maximum lifetime BMI an additional or more important indicator of mortality hazard? Second, is there an additional benefit of using body shape silouettes for current or retrospective reporting of early life or maximum weight, for understanding health risk? Third, and most importantly, are the associations between these multiple measures of adiposity universal across context as biological risks as theorized currently in the literature, or are they potentially explained by confounding due to social class in developed countries? Prior validation studies of recall of early life weights show that correlation between actual and recalled weight is 0.73 for men and 0.74 for women (Perry, Byers et al. 1995).

Our analysis explores a unique opportunity to answer these questions given the parallel collection of virtually identical representative population based data in the United States and Costa Rica. Not only does this give us the potential to examine the universality of associations in a high GDP and middle GDP country, but it also allows us to examine whether similar associations between obesity and mortality risk exist in a country with different socioeconomic relationships with obesity. In the United States, social class is strongly correlated with obesity, in particular among women, while this association does not exist in Costa Rica. If universal associations between body weight measures across the life course are found to exist in both contexts, this evidence would further support the hypothesis that associations found in the United States and other developed countries with strong social class gradients in obesity may be biologically universal. Alternatively, if associations differ in Costa Rica, it may call in to question the fundamental biological relationships between weight and mortality risk, or suggest ways in which our current theories of this association should be modified.

An earlier analysis of the effect of baseline BMI and waist circumference on three-year prospective mortality in older Costa Ricans showed that the relationship is complex. The risk of dying increases with body mass and, especially with waist circumference, but only in individuals younger than 75 years. After this age, the relationship reverses and body fat appears to be a protective factor against death (Rosero-Bixby, Brenes-Camacho and Mendez-Chacon 2008).

We examine the relationship between multiple measures of obesity (age 25, maximum lifetime and current) and the four cardiovascular risk factors that are most impacted by obesity: systolic blood pressure, HbA1c, HDL cholesterol and triglycerides. Each of these biomarkers in turn are strong, established risk factors for CHD mortality. This relationship between biomarkers and mortality does not appear to be context dependent, but is understood to be a biologically universal relationship (Yusuf, Hawken et al. 2004).

Methods

Samples

Data from Costa Rica is from the Costa Rican Study on Longevity and Healthy Aging (CRELES), a longitudinal, nationally representative, probabilistic sample of adults aged 60 and over selected from the 2000 census database. A selected sub-sample of this population (n=1329 men, n=1498 women) with over-sampling of the oldest old completed an in depth survey in their household from November 2004 to September 2006 which is the basis of the analytic sample for our analyses. This sub-sample was drawn from a larger number of individuals selected from the 2000 census with the following non-response rates: 19% of individuals were deceased by the contact date, 18% could not be found, 2% had moved and 4% rejected the interview. Among those interviewed, 95% provided a fasting blood sample. Data from the United States is from the National Health and Nutrition Examination Survey 1999-2004, restricted to adults aged 60 and over (n=2411 men, n=3196 women). This cross-sectional data is representative of the non-institutionalized population of the United States.

Measures

BMI was calculated from weight and height. All analyses rely on currently measured height. Current weight was both measured and self-reported. Weight at age 25 and maximum lifetime weight was self-reported. Biomarkers were measured similarly in each sample, with details described elsewhere (Rehkopf, Dow et al. 2010). Since the absolute level of educational attainment has different social and economic meaning in each country, it does not make sense to use the same categories of education. For Costa Rica, educational attainment was categorized into three groups: less than three years of education, from three to six years of education (elementary school comprises six grades), and at least one year of high school. For the United States, we use the educational categories of less than high school, high school or greater than high school.

Models

Ordinary least squares regression models were used to examine the association between multiple measures of weight and the four biomarkers of focus. In addition to the variables controlled for as shown in Table 3, all models controlled for age, age squared, gender and a gender age interaction term (coefficients not shown). All analyses accounted for over-sampling and clustered sampling using the survey package in STATA 10. Sampling weights and clustering were at the PSU level (n=49) in NHANES and at the health area level in CRELES (n=60).

Results

Table 1 shows column means and percents of the Costa Rican and United States samples. The age distributions are similar. Current measured BMI is slightly higher in the United States than in Costa Rica. Self-reports of weight for determining BMI are higher than measured values in Costa Rica, but lower in the United States. Age 25 BMI is lower in Costa Rica than the United States for men but higher for women, as is maximum lifetime attained body weight. Systolic blood pressure is higher in Costa Rica, while Trigylcerides and HDL cholesterol are higher in the United States. HbA1c is higher in the U.S. among men, but lower among women.

Table 2 shows Pearson correlation coefficients of the relationships between different measures of BMI and body size in Costa Rica and the United States by gender. There is a stronger association between self-reported BMI and measured BMI in the United States compared to Costa Rica. There is also a stronger correlation between maximum BMI and current BMI in the United States. Age 25 BMI and current measured BMI have similar correlations in both countries among women, but among men the Costa Rican correlation is much lower.

Table 3 presents 4 models (or 3 in the United States) examining the association between multiple measures of weight and four CHD risk biomarkers. All models also control for age, age-squared, gender and an age-gender interaction, coefficients not shown. In Costa Rica, current BMI (model 1) is significantly associated with higher HbA1c, lower HDL (higher risk), and higher trigylcerides. These same associations are seen in the United States. The association with systolic blood pressure was not significant in either country. Model two also includes BMI at age 25 and Maximum lifetime BMI. In Costa Rica, higher maximum lifetime BMI was unexpectedly predictive of lower triglycerides, and borderline significant with increased HbA1c. In the United States, maximum lifetime BMI was additionally predictive of increased HbA1c. In addition, lower BMI at age 25 was predictive of higher later life levels of HbA1c. Model 4 shows results after additionally adjusting for education. Results of the primary models are generally robust to the inclusion of educaiton

In Costa Rica, we were also able to examine whether body sillouettes offered additional power for predicting biomarkers (Model 3). This appears to be the case for Triglycerides, where current shape is significantly predictive of level of trigylcerides. It also appears that shape at age 25 is inversely predictive of triglycerides, consistent with a pattern of early life low weight (possibly undernutrition) and later life obesity as particularly hazardous for triglyceride levels. These findings were not significant when individuals were asked to recall their exact weight at age 25.

Conclusions

As expected, we find strong and statistically significant relationships between HbA1c, HDL cholesterol and Triglycerides with BMI. In testing prior suggestions of important life course impacts on cardiovascular risk markers, we find some support for the impact of early life BMI and maximum lifetime BMI on these risk markers. In both Costa Rica and the United States, in models controlling for attained education, we find that maximum lifetime BMI is most or equally predictive of HbA1c (as compared to other BMI measures). It is likely that these associations are conservative given the likelihood of measurement error in the recall of weight. Findings with trigylcerides suggest that recall of body shape may provide greater ability to capture early size than recall of weight. In addition, the findings across models that maximum lifetime body weight in Costa Rica predicts *lower* levels of triglycerids may suggest a mechanism explaining some prior paradoxical findings of the protective effects of obesity on mortality (Rosero-Bixby, Brenes-Camacho and Mendez-Chacon 2008). The population health implications of these findings suggest that some of the protective or adverse affects of younger adult obesity may be attenuated with changes in weight later in life, but that for some factors (HbA1c) maximum weight may retain strong importance.

Tables

Table 1: Demographic and health related characteristics of Costa Rica (CRELES) and the United States (NHANES) (column percent or mean)

	Costa Rica		United States	
	n=1329	n=1498	n=2411	n=3196
	men	women	men	women
Demographic				
Age				
60-64	31%	29%	26%	24%
65-74	42%	41%	44%	40%
75-84	21%	22%	24%	29%
>85	6%	7%	6%	8%
education (Costa Rica/United States)				
<3 years elementary / <high school	28%	28%	29%	31%
> 3 years elementary / high school	49%	52%	24%	32%
at least 1 year high school / >high school	23%	20%	46%	36%
married or partner	77%	47%	77%	46%
Anthropometric				
Current BMI (measured weight)	26.1	27.8	28.1	28.2
Current BMI (self-reported weight)	26.7	28.6	27.5	27.3
Age 25 BMI (self-reported weight)	22.9	23.7	23.8	21.9
Maximum BMI (self-reported weight)	28.5	31.0	29.9	29.8
Current body size (silhouette 1-9)	4.3	4.3	-	-
Age 25 body size (silhouette 1-9)	2.8	2.7	-	-
Maximum body size (silhouette 1-9)	5.4	5.3	-	-
Cardiovascular biomarker Risk Factors				
Systolic blood pressure	151	155	134	141
HbA1c	5.7	6.0	5.9	5.8
Triglycerides	167	172	153	151
HDL cholesterol	42	49	47	59

Table 2: Correlations (Pearson) between different BMI measures in Costa Rica (CRELES) and the United States (NHANES)

Men CRELES

	BMI current Measured	BMI current Reported	BMI age 25 Reported	BMI Maximum Reported	Silhouette Current	Silhouette Age 25	Silhouette Maximum
BMI current Measured	1.00						
BMI current Reported	0.77	1.00					
BMI age 25 Reported	0.062	0.16	1.00				
BMI Maximum Reported	0.52	0.63	0.32	1.00			
Silhouette Current	0.66	0.57	-0.001	0.36	1.00		
Silhouette Age 25	-0.0031	0.033	0.38	0.057	0.20	1.00	
Silhouette Maximum	0.56	0.48	0.046	0.41	0.79	0.35	1.00

Women CRELES

	BMI current Measured	BMI current Reported	BMI age 25 Reported	BMI Maximum Reported	Silhouette Current	Silhouette Age 25	Silhouette Maximum
BMI current Measured	1.00						
BMI current Reported	0.80	1.00					
BMI age 25 Reported	0.31	0.35	1.00				
BMI Maximum Reported	0.69	0.67	0.41	1.00			
Silhouette Current	0.67	0.55	-0.030	0.40	1.00		
Silhouette Age 25	0.070	0.098	0.43	0.17	0.15	1.00	
Silhouette Maximum	0.54	0.45	0.088	0.50	0.76	0.40	1.00

Men NHANES

	BMI current Measured	BMI current Reported	BMI age 25 Reported	BMI Maximum Reported
BMI current Measured	1.00			
BMI current Reported	0.94	1.00		
BMI age 25 Reported	0.37	0.41	1.00	
BMI Maximum Reported	0.82	0.84	0.54	1.00

Women NHANES

	BMI current Measured	BMI current Reported	BMI age 25 Reported	BMI Maximum Reported
BMI current Measured	1.00			
BMI current Reported	0.94	1.00		
BMI age 25 Reported	0.29	0.37	1.00	
BMI Maximum Reported	0.81	0.84	0.51	1.00

Table 3: OLS Regression Models of correlation between multiple life course BMI measures and current levels of cardiovascular risk biomarkers (systolic blood pressure, HbA1c, LDL cholesterol, Triglycerides), Costa Rica (CRELES) and the United States (NHANES)

Costa Rica

Systolic Blood Pressure	Model 1	Model 2	Model 3	Model 4
BMI – Current	0.10 (0.29)	0.018 (0.33)	0.098 (0.41)	0.040 (0.35)
BMI – Age 25		0.16 (0.18)	0.077 (0.26)	0.091 (0.18)
BMI – Maximum		-0.16 (0.26)	-0.17 (0.23)	-0.19 (0.24)
Shape – Current			-0.30 (1.28)	
Shape – Age 25			0.62 (1.42)	
Shape – Maximum			0.020 (1.80)	
Education – middle				6.07 (4.22)
Education – highest				0.34 (3.77)

HbA1c	Model 1	Model 2	Model 3	Model 4
BMI – Current	0.014 (0.006)	-0.002 (0.012)	0.009 (0.015)	0.00046 (0.012)
BMI – Age 25		-0.001 (0.008)	-0.007 (0.096)	-0.004 (0.008)
BMI – Maximum		0.016 (0.009)	0.014 (0.008)	0.015 (0.008)
Shape – Current			-0.07 (0.049)	
Shape – Age 25			0.025 (0.042)	
Shape – Maximum			0.044 (0.050)	
Education – middle				-0.16 (0.19)
Education – highest				-0.32 (0.20)

HDL	Model 1	Model 2	Model 3	Model 4
BMI – Current	-0.34 (0.083)	-0.46 (0.12)	-0.42 (0.15)	-0.47 (0.12)
BMI – Age 25		0.036 (0.13)	0.086 (0.14)	0.07 (0.13)
BMI – Maximum		0.07 (0.092)	0.044 (0.092)	0.09 (0.09)
Shape – Current			-0.32 (0.58)	
Shape – Age 25			-0.39 (0.42)	
Shape – Maximum			0.22 (0.75)	
Education – middle				1.8 (2.1)
Education – highest				7.1 (2.1)

Triglycerides	Model 1	Model 2	Model 3	Model 4
BMI – Current	1.4 (0.52)	3.2 (0.92)	0.95 (1.4)	3.3 (0.92)
BMI – Age 25		-0.69 (0.88)	0.86 (0.80)	-0.74 (0.93)
BMI – Maximum		-1.79 (0.67)	-1.35 (0.68)	-1.8 (0.68)
Shape – Current			10.9 (4.6)	
Shape – Age 25			-7.8 (2.9)	
Shape – Maximum			-4.0 (4.8)	
Education – middle				-14 (20)
Education – highest				-16 (21)

United States

Systolic Blood Pressure	Model 1	Model 2	Model 3	Model 4
BMI – Current	0.067 (0.074)	0.22 (0.15)	-	0.24 (0.15)
BMI – Age 25		-0.11 (0.14)	-	-0.099 (0.14)
BMI – Maximum		-0.14 (0.17)	-	-0.17 (0.17)
Education – middle			-	-0.98 (1.0)
Education – highest			-	-2.3 (1.1)

HbA1c	Model 1	Model 2	Model 3	Model 4
BMI – Current	0.016 (0.002)	0.009 (0.005)	-	0.011 (0.005)
BMI – Age 25		-0.017 (0.007)	-	-0.016 (0.007)
BMI – Maximum		0.014 (0.008)	-	0.011 (0.007)
Education – middle			-	-0.17 (0.038)
Education – highest			-	-0.22 (0.039)

HDL	Model 1	Model 2	Model 3	Model 4
BMI – Current	-0.85 (0.074)	-0.85 (0.15)	-	-0.87 (0.15)
BMI – Age 25		0.056 (0.099)	-	0.044 (0.099)
BMI – Maximum		-0.018 (0.13)	-	0.031 (0.13)
Education – middle			-	2.59 (0.81)
Education – highest			-	3.22 (1.03)

Triglycerides	Model 1	Model 2	Model 3	Model 4
BMI – Current	2.91 (0.36)	3.3 (0.64)	-	3.4 (0.63)
BMI – Age 25		-1.53 (0.62)	-	-1.5 (0.62)
BMI – Maximum		-0.14 (0.65)	-	-0.27 (0.61)
Education – middle			-	-5.1 (5.3)
Education – highest			-	-8.3 (4.6)

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