HHS Public Access

Author manuscript

Public Health Nutr. Author manuscript; available in PMC 2019 February 01.

Published in final edited form as:

Public Health Nutr. 2019 February ; 22(2): 314–323. doi:10.1017/S1368980018002276.

Life Course Body Mass Index and Biomarkers in Persons 60 and Older: a Comparison of the United States and Costa Rica

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Abstract

Objective: There is a large literature linking current body mass index (BMI) to levels of cardiovascular risk biomarkers, but it is unknown whether measures of BMI earlier in the life course and maximum BMI are predictive of current levels of biomarkers. The objective of this study is to determine how current, maximum and age 25 body mass index among individuals over the age of 60 are associated with their current levels of cardiovascular risk biomarkers.

Design: Cross-sectional study with retrospective recall.

Setting: Costa Rica (n=821) and the United States (n=4110).

Subjects: Nationally representative samples of adults aged 60 and over.

Results: We used regression models to examine the relationship between multiple meaures of body mass index with four established cardiovascular risk biomarkers. The most consistent predictor of current levels of systolic blood pressure, triglycerides and HDL cholesterol is current BMI. However, maximum BMI is the strongest predictor of hemoglobin A1c and is also related to HDL cholesterol and triglycerides. Hemoglobin A1c is independent of current BMI. We find that these relationships are consistent between Costa Rica and the United States for hemoglobin A1c and for HDL cholesterol.

Conclusions: Current levels of cardiovascular risk biomarkers are not only the product of current levels of BMI, but also of maximum lifetime BMI, in particular for levels of hemoglobin

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AUTHOR CONTRIBUTIONS:

WHD and LR designed the CRELES study. WHD, LR and DHR developed the study question and analysis approach. DHR and AD analyzed the data. DHR drafted the manuscript. All authors were involved in interpreting results, editing the manuscript for content and approved the final version of the manuscript.

DISCLOURE:

The authors declared no conflicts of interest.

ETHICAL STANDARDS DISCLOSURE:

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the University of Costa Rica's Committee on Ethics and Science (*Comité Etico-Científico*). Written informed consent was obtained from all subjects.

A1c and for HDL cholesterol. Managing maximum obtained BMI over the life course may be most critical for maintaining the healthiest levels of cardiovascular risk.

Keywords

Obesity; life course; Latin America; cardivoascular disease; biomarkers

Introduction

Despite a tremendous research effort, substantial questions still remain about when, where and how obesity matters as a driver of mortality (1, 2). For estimating the burden of obesity on health, the majority of studies have been done in high income countries, and have most frequently used only single measurements of obesity (measured as current BMI) that are typically taken in middle to later life (3, 4). Using nationally representative data in the U.S., work has shown that maximum lifetime body weight is the best predictor of mortality risk, as opposed to the weight that was measured at a particular point in time (5). A critical contributing factor to this finding was that associations with mortality were attenuated among individuals who had dramatic weight loss due to illness prior to death, which is reflected in a point in time measure but not in maximum lifetime body weight. A small number of studies have suggested that earlier life measures of weight are also relevant for predicting biological risk factors for cardiovascular disease (6), particularly for cholesterol (7). Further understanding of which measures of body weight predict later life biomarkers risk factors will help to understand the biological pathways of how life course weight measures correlate with mortality.

The effect of BMI on later health outcomes such as mortality and cardiovascular disease has most commonly been examined from the perspective of BMI at early ages. Obesity in early childhood or adolescence is similarly predictive of adverse health outcomes later in life (8–10). Under the cumulative disadvantage theory, which posits that the disadvantages of obesity accumulate over time, it may be expected that high BMIs in early adulthood or at any point in the life course may also impact later health (11). High BMI at age 25 has been associated with increased functional limitations and mortality in both men and women more than 25 years later (12, 13).

Our current analysis addresses methodological and substantive questions that build on the current evidence base. First, is current BMI, BMI early in life (at age 25), or maximum lifetime BMI the most important predictor of biomarkers later in life? Second, are the associations between these multiple measures of adiposity universal across context as biological risks (as theorized currently in the literature), or might these associations be explained by confounding or effect modification that differ between countries? While infrequently investigated due to lack of comparable data, prior studies of demographic relationships with risk biomarkers have revealed suprising differences across context (14).

The collection of comparable nationally representative data in the United States and Costa Rica allows us to examine whether our findings are consistent across place. In the United States, social class is strongly and negatively correlated with obesity (less obesity at higher social classes), in particular among women, while in Costa Rica there is no association

among women, and a positive (more obesity at higher clases) association among men (15). 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 high income 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 life course weight and biological risk factors for cardiovascular disease.

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. Due to missing data on self-reported weight at age 25 and maximum lifetime weight, the total analytic sample in Costa Rica is 821, and in the United States is 4110.

Measures

Exposure: 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. We also calculated change in weight over two periods of time – between maximum weight and current weight, and age 25 weight and current weight. 3.5% of the sample in Costa Rica and 4.1% of the sample in the United States attained their maximum weight before the age of 25. 28% of the sample was at their maximum weight currently in Costa Rica and 24% of the sample in the United States.

Outcomes: systolic blood pressure, hemoglobin A1c, HDL cholesterol and triglycerides were measured similarly in each sample, with details described elsewhere (15).

Potential confounders: 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 in each country. 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, and greater than high school. In both NHANES and CRELES, current smoking was assessed

by the question, “Do you smoke now?” In CRELES, sedentary behavior was defined as participants responding “no” to the question “In the last 12 months, did you exercise regularly or do other physical rigorous activities like sports, jogging, dancing or heavy work, three times a week?” In NHANES, sedentary behavior was assessed by whether individuals reported physical activity fewer than 13 times in the last 30 days, and answered “No” to the question of “you do heavy work or carry heavy loads” as an average level of physical activity each day.

Models

Figures present unadjusted associations from generalized additive models using penalized regression splines (16). Ordinary least squares regression models were then used to examine the association between the multiple measures of BMI and the four biomarkers of focus controlling for potential confounding factors. In addition to the variables controlled for as shown in Table 2, all models contain the additional covariates not shown: age, age squared, Hispanic (U.S. only), black (U.S. only), gender, age by gender interaction, education (as 3 indicator variables), wealth (income in U.S.), foreign born, current smoker and physically active. There is not an equivalently important race or ethnicity variable in Costa Rica that is similar to those used in the United States, the most relevant characteristics are captured by foreign born, which is used in models in both contexts. Because wealth data is not available in NHANES in the United States, we use the poverty income ratio instead, as a continuous measure that ranges from zero to 5, where all individuals with a ratio of greater than 5 are set to 5. In order to examine the extent to which the associations are due to levels of current weight, the “+ current BMI” is an identical model but additionally controls for current measured BMI. All analyses accounted for over-sampling and clustered sampling using the survey package in STATA 11. Sampling weights were used along with clustering at the PSU level (n=49) in NHANES and at the health area level in CRELES (n=60).

Our primary modeling strategy is to examine each of the three BMI measurements (current, age 25 and maximum) in separate models. These models are our primary focus for inference because they avoid collinearity between BMI measures and avoid controlling for measures of BMI that come after other measures. However, we also fit two other types of models as a secondary focus. First, we fit models additionally including current BMI, even though it is likely on the causal pathway between early BMI and contemporaneous biomarker measurements. We fit these models because it is of substantive interest to understand whether BMI measures earlier in the life course are associated with varitation in biomarker outcomes independent of current BMI, since most literature focuses on current measures of BMI. Finally, based on a similar rationale, we fit models with all three BMI measurements in the model. In each of these secondary models, while there is a potential for collinearity, the reasonable widths of our confidence intervals suggest that this is not empirically a problem with our estimates, even as results must be interpreted with caution. Thus, while the primary models are the focus of inference, when results are consistent across models this provides additional justification for the potential importance of measures of BMI that occur at age 25 or at maximum BMI.

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 depends on age (17). This age modification of the relationship between BMI and mortality is similarly observed in the United States (3). Based on this, we will examine whether we find effect modification (interaction) in the BMI-biomarker relationship by age strata (age 60 to 75 and 75 and older). We will also examine effect modification by gender given different levels of biomarkers.

Results

descriptive

Table 1 shows column means or percents of the Costa Rican and United States full population samples as compared to the analytic sample on which we have all observations of BMI at age 25, maximum BMI and current BMI. In both the Costa Rican and United States samples, the demographic composition of the population is similar, albeit with fewer individuals over the age of 85 in the analytic sample, particularly in Costa Rica. Therefore, caution should be taken for generalizing our findings to the population age 85 and older. There are also some differences in distribution of education, but these differences are of less concern due to the different categories used in each country. Overall, there is a dramatic difference in the level of being physically active in Costa Rica as compared to the United States. Levels of BMI and the outcomes we examine are nearly identical between the full sample and the analytic sample, and levels are very similar overall between Costa Rica and the United States. Tables S1 and S2 show Pearson correlation coefficients of the relationships between different measures of BMI 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.

Figure 1 shows the unadjusted associations between current measured BMI (yellow line), age 25 BMI (dark green line), and maximum BMI (olive green line) with four biomarkers of cardiovascular risk. Shaded regions show 95% confidence intervals around the plotted relationship. There is no meaningful relationship between all three BMI measures and systolic blood pressure in Costa Rica, and there is a weak and similar relationship with all three measures in the United States. For hemoglobin A1c, there is a stronger relationship with both current and maximum BMI in Costa Rica, but the strongest relationship is with age 25 BMI in the United States. There are higher levels of triglycerides with current and maximum BMI in Costa Rica and the United States. Finally, for HDL cholesterol, there are lower (worse) levels with higher current and maximum BMI in both countries, but these relationships are stronger in the United States.

Figure 2 shows the unadjusted associations between currently measured BMI and the four biomarkers of focus. Each plot shows the relationship stratified by age and gender: men age >= 75 (yellow line), men age 60–74 (dark green line), women age >=75 (olive green line), women age 60–74 (medium green line). Shaded regions show 95% confidence intervals around the plotted relationship. The column on the left shows the relationships in Costa Rica, and the column on the right shows the relationships in the United States. In both Costa

Rica and the United States, the unadjusted relationship between current measured BMI and systolic blood pressure is fairly weak, with little evidence of an association within any of the age and gender subgroups. There is evidence of a more substantial relationship between BMI and HbA1c, which does not differ substantially by subgroup, although there is evidence for a slightly stronger relationship among men age 60–74 in the United States. For triglycerides, there is some evidence of a stronger relationship with current BMI among men and women age 60–74, in both Costa Rica and the United States. Finally, for HDL cholesterol, there appear to be gender differences in the association, in both Costa Rica and the United States, with a given level of BMI associated with lower HDL cholesterol among men as compared to women, even as the shape and direction of the association (higher BMI associated with lower HDL cholesterol) was generally consistent across gender.

Primary models of different measurements of BMI

Table 2 presents the results of 5 models for each biomarker, for each country, a total of 40 models. Model 1 presents current BMI as the primary predictor of interest, Model 2 presents age 25 BMI and model 3 presents maximum BMI. Only the primary coefficient of interpretation from each model is presented, but each of the models also includes the covariates: age, age squared, Hispanic (U.S. only), black (U.S. only), gender, age*gender interaction, education (as 3 indicator variables), wealth (income in U.S.), foreign born, current smoker and physically active. These are the primary models for inference because they do not include multiple measures of BMI which may be on the causal pathway or may be too collinear to disentangle associations. In addition, the coefficients shown in the second and fourth rows of the results for each biomarker, labeled “+ current BMI” also include current measured BMI (in all models except for Model 1, which already presents current BMI). Models 1 and 3 also include Age 25 BMI since it occurs prior to current and maximum BMI, and is a potential confounder. Statistically significant associations ($p<0.05$) are bolded.

The most consistent associations observed are that current BMI is the strongest predictor of levels of biomarkers, and these associations are consistent between the United States and Costa Rica. However, for hemoglobin A1c and for HDL cholesterol, there are also strong and consistent relationships with maximum BMI. For hemoglobin A1c these assocations are not markedly diminished even after controlling for current levels of BMI. In the United States only, there were associations between age 25 BMI and hemoglobin A1c, and an inverse association with trigylcerides when controlling for current BMI. In addition, maximum BMI has a positive association with triglycerides in the United States, but an inverse association in Costa Rica after controlling for current BMI.

Table 3 presents results that include all 3 measures of BMI in the same model. This is the same model presented in Table 2 for maximum BMI with current BMI, but in table 3 we present all three coefficients from each of these models. Results are generally consistent with our interpretations of the Table 2 data, but these full models show that hemoglobin A1c is more strongly associated with maximum BMI than it is with current BMI. While these coefficients should be interpreted cautiously due to causal ordering of BMI measures and potential collinearity, the similarity of coefficients as compared to the models shown in table

2 supports the relevance of age 25 and maximum BMI to current measures of cardiovascular risk biomarkers.

Differences in the associations by age and gender

We additionally fit the full models (with all three measures of BMI) including interaction terms between BMI and age (<75 as compared to >=75) and between BMI and gender. We examined interactions in each of our three main models, for four outcomes in two countries, for a total of 24 interactions with age and 24 interactions with gender. We use a p-value significant threshold of alpha = 0.10 as a guideline for reporting stratified models, while acknowledging that we would identify four models to stratify by chance alone. There were some differences by age and gender, although none of these differences were larger in terms of magnitude or direction, and there were not consistent patterns in these interactions, for example, assocations did not tend to be stronger for younger individuals or a particular gender, although there were four by gender in the United States as compared to two in Costa Rica. We found four terms that met this criteria in Costa Rica, and 7 interactions in the United States, slightly more than what we would find by chance alone.

In Costa Rica, for the association between current BMI and hemoglobin A1c, the association in the full model was 0.0074 (−0.025, 0.040) among those under the age of 75, but was 0.053 (0.031, 0.076) among those over the age of 75. For the association between current BMI and triglycerides, the association was 5.7 (2.0, 9.3) among men and 2.4 (0.74, 4.2) among women. For the association between current BMI and HDL cholesterol, the association was −1.1 (−1.5, −0.66) among men and −0.19 (−0.47, 0.093) among women.

In the United States, for the association between maximum BMI and hemoglobin A1c, it was 0.016 (−0.0092, 0.042) for those age 75 and over, and 0.056 (0.030, 0.080) for those under age 75, while for HDL cholesterol it was −0.36 (−1.1, 0.35) for those age 75 and over, and 0.24 (−0.067, 0.55) for those under age 75. For the association between systolic blood pressure and early BMI, it was −0.28 (−0.68, 0.13) among men and 0.23 (−0.16, 0.61) among women. For the association between hemoglobin A1c and maximum BMI, it was 0.07 (0.05, 0.10) among men, and 0.032 (0.012, 0.053) among women. For the association between trigylcerides and current BMI, it was 6.0 (2.6, 9.3) among men and 2.5 (1.3, 3.6) among women. Finally, for the the associations of HDL cholesterol with maximum BMI it was 0.32 (0.037, 0.60) among men and −0.11 (−0.43, 0.22) among women, and with current BMI, it was −1.0 (−1.3, −0.68) among men and −0.73 (−1.1, −0.40) among women.

Discussion

In testing competing theories of the importance of life course BMI impacts on contemporaneous levels of cardiovascular risk markers, we find support for the importance of maximum lifetime BMI in both Costa Rica and the United States, but these relationships differ depending on the CHD risk biomarker examined. The most important and consistent predictor of current levels of systolic blood pressure, triglycerides and HDL cholesterol is current BMI. However, maximum BMI is the strongest predictor of hemoglobin A1c, and is also related to HDL cholesterol and to a lesser extent triglycerides. For hemoglobin A1c, this association is independent of current BMI. There were neither consistent nor strong

associations with biomarkers and BMI at the age of 25. It is useful to note that the relationship between BMI and the four biomarkers examined did not differ substantially or consistently between age 60–74 as compared to age 75 and above, as can be assessed visually in the descriptive plots in Figure 2, and by the magnitude of the interactions we reported in the text.

The greatest limitation of our analysis is that we do not have measured weight across participant ages, but instead must rely on participant recall. It is unknown whether this recall is differential or non-differential, and it is not possible to test this empirically without a validation sample. If non-differential, we would expect that this would be a conservative bias of the association of age 25 BMI and maximum BMI on the examined biomarker outcomes. If differential, it is unknown in which direction the coefficients of association would be biased. Despite this limitation, we believe that this bias is not likely to be severe. First, prior work has found that recall of earlier life weight is more accurate than one might expect (18). In particular, one study determined that while the average self-reported weight of women at age 18 was marginally lower than their measured weight at that age, women generally recalled their weight with a fair degree of accuracy, with a correlation greater than 0.8 between recalled and measured past weight and BMI (19). An additional validation study on recall of early life weights showed that correlation between actual and recalled weight is 0.73 for men and 0.74 for women (20). With respect to the potential differential nature of the bias, we control for a substantial number of demographic factors in all models that may be associated with any tendency to over or under report weight. Finally, we also fit models controlling for current weight, arguably the factor that may be most correlated with misreporting of prior weight. Thus, in order for our results that include age 25 BMI or maximum BMI to have a non-conservative bias, differential reporting must be conditional on a large number of demographic factors and current weight, which we believe to be unlikely. This is particularly a strong argument because the outcomes we examine are not self-reported, but are the result of biological tests. While sensitivity analyses of differential and non-differential misclassification would offer additional support for this, the current state of development of these methods limits them to dichotomous exposures or models that do not control for covariates (21–23). A further limitation is that we had a large number of missing observations of self-reported age 25 BMI and maximum lifetime BMI, so our findings may not be generalizable to the population. However, as shown in table 1, the characteristics of the full population and the population examined here are very similar.

While our models statistically controlled for measures of socieconomic position in both contexts as potential confounding factors, future work should investigate the role that social exposures play in life course determinants of obesity. This ideally should be investigated in studies with multiple measures of obesity and social measures over time given the potential for causality to run in both directions (24, 25).

We found unexpected inverse associations for age 25 BMI and triglyceride levels in the U.S., and maximum BMI levels and triglyceride levels in Costa Rica, when controlling for current BMI. That is, only when conditional on current BMI, higher levels of BMI were associated with lower levels of triglycerides. This is unlikely to be explained by collinearity as levels of each of these covariates were not highly enough correlated (Table S1 and Table S2). These

findings should be interpreted cautiously, however, because they are from models controlling for current BMI, which is a strong correlate of trigylceride level, and on the causal pathway between the exposures and outcome. Analysis of these relationships in other datasets is required as we did not observe similar associations in Costa Rica and the United States, so it is unclear how generalizable these findings are.

Our findings using biomarkers support work that finds maximum lifetime BMI to be a key determinant of mortality (5), work that shows BMI change in early to middle adulthood is associated with greater chronic disease risk later in life (26). Although we did not test it in this study, our findings are consistent with known cardiovascular risk markers underlying this relationship. Our conclusions are also consistent with prior work in the United States that showed most of the relationship between biomarkers and obesity were due to current BMI, with similar findings that there were some associations with HbA1c that were not explained by current BMI (27). Our comparative work builds to show similar findings in Costa Rica as well as also incorporating a consideration of maximum BMI. Our primarily null finding regarding age 25 BMI suggests that this factor is not important for later life levels of biomarkers, and may be less important to consider in future work as compared to the burden of maximum lifetime BMI. The population health implications of our findings support continued efforts to manage BMI across the life course given the longer-term health risks associated with maximum lifetime BMI. Future studies of the population impacts of obesity should include measures of maximum lifetime BMI.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

FUNDING:

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). Dr. Rehkopf is supported by the National Institute of Aging (K01AG047280).

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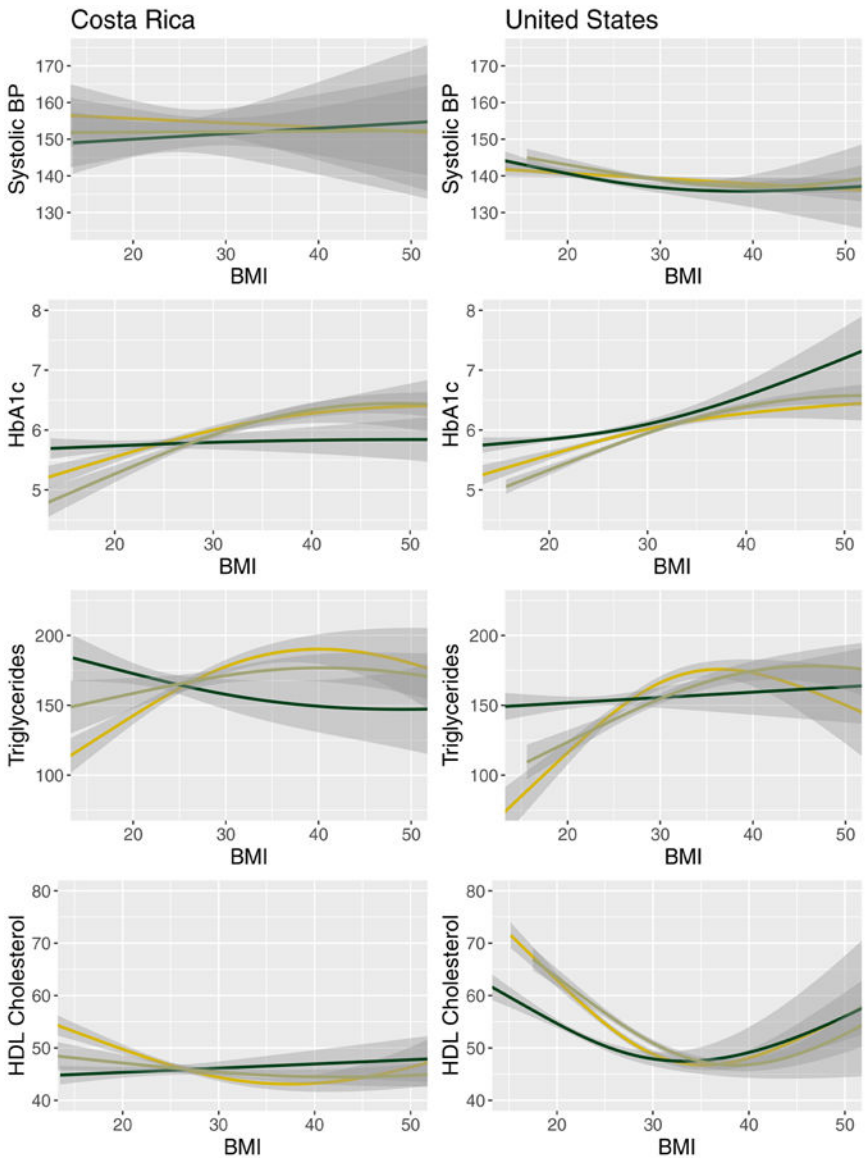

Figure 1.

Plots show unadjusted associations between current measured BMI (yellow line), age 25 BMI (dark green line), and maximum BMI (olive green line) with four biomarkers of cardiovascular risk, systolic blood pressure (row 1), hemoglobin A1c (row 2), Trigylcerides (row 3), HDL cholesterol (row 4). The column on the left shows the relationships in Costa Rica, and the column on the right shows the relationships in the United States. Shaded regions show 95% confidence intervals around the plotted associations.

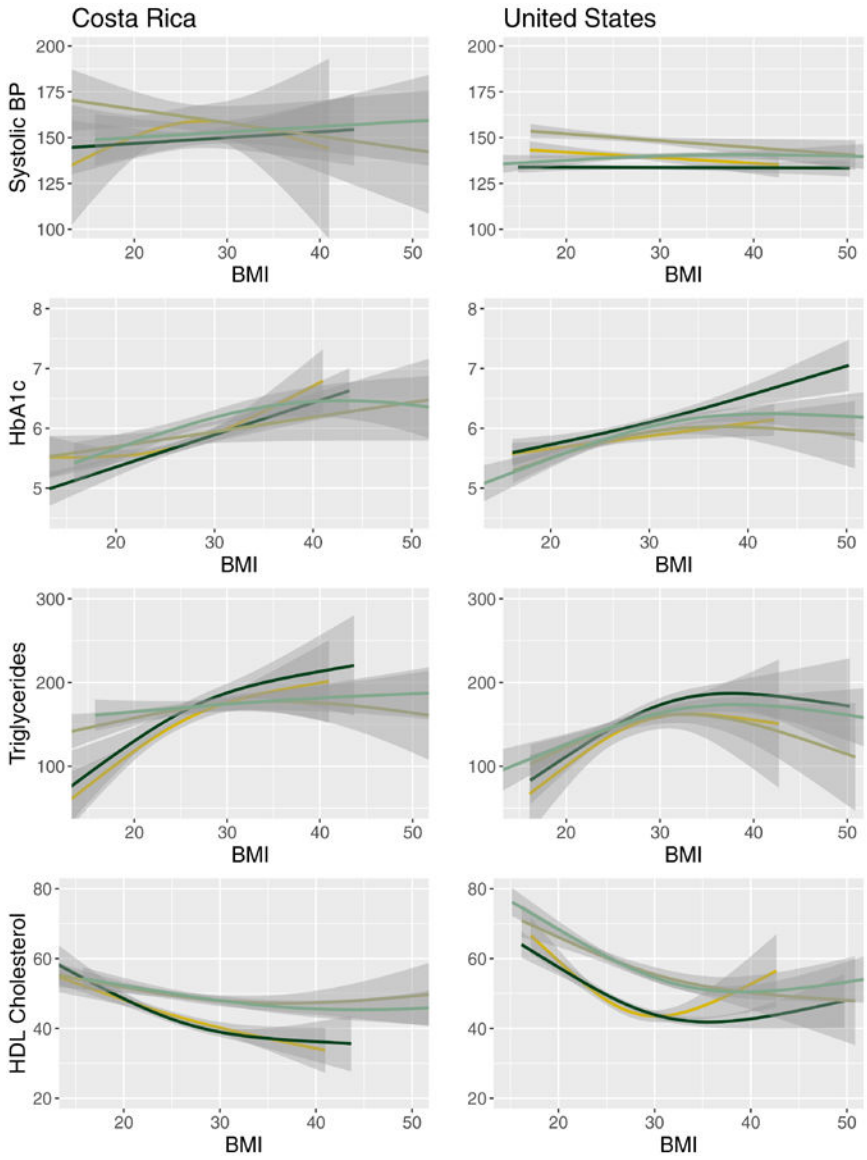

Figure 2.

Plots show the unadjusted associations between currently measured BMI and the four biomarkers of focus, systolic blood pressure (row 1), hemoglobin A1c (row 2), Trigylcerides (row 3), HDL cholesterol (row 4). The column on the left shows the relationships in Costa Rica, and the column on the right shows the relationships in the United States. Each plot shows the relationship stratified by age and gender: men age >= 75 (yellow line), men age 60–74 (dark green line), women age >=75 (olive green line), women age 60–74 (medium green line). Shaded regions show 95% confidence intervals around the plotted associations. Smoothed estimates are from generalized additive models.

Table 1.

Demographic and health related characteristics comparing the full sample to the analytic sample, Costa Rica (CRELES) and the United States (NHANES) (column percent or mean)

	Costa Rica		United States	
	n=2827	n=821	n=5607	n=4110
	Full	Analytic	Full	Analytic
Demographic				
Age				
60–64	30%	39%	25%	26%
65–74	42%	43%	42%	43%
75–84	22%	16%	27%	26%
>=85	6.6%	1.5%	7.1%	5.7%
Education (Costa Rica/United States)				
<3 years elementary / <high school	13%	5.7%	30%	29%
> 3 years elementary / high school	37%	28%	29%	29%
at least 1 year high school / >high school	49%	67%	41%	42%
Married or partner	62%	71%	59%	61%
Foreign birthplace	4.8%	3.9%	11%	11%
Health Behaviors				
Currently smoking	10%	11%	12%	12%
Physically Active	69%	58%	7%	7%
Anthropometric				
Current BMI (measured weight)	27	27	28	28
Age 25 BMI (self-reported weight)	23	23	23	23
Maximum BMI (self-reported weight)	30	30	30	30
Cardiovascular biomarker Risk Factors				
Systolic blood pressure	145	144	138	138
HbAlc	5.8	5.7	5.8	5.8
Triglycerides	170	172	152	152
HDL cholesterol	46	46	54	53

Table 2:

OLS Regression Models of correlation between BMI measures and current levels of biomarkers (systolic blood pressure, HbA1c, triglycerides and HDL cholesterol), Costa Rica (CRELES) and the United States (NHANES).

	Model 1	**Model 2**	**Model 3**
Systolic Blood Pressure	**Current BMI**	**Age 25 BMI**	**Maximum BMI**
Costa Rica	**0.43 (0.12, 0.74)**	0.066 (−0.21, 0.34)	0.21 (−0.096,0.51)
+current BMI	-	−0.037 (−0.32, 0.25)	−0.050 (−0.47, 0.37)
United States	0.11 (−0.063,0.28)	−0.044 (−0.29, 0.21)	0.015 (−0.16, 0.19)
+current BMI	-	−0.10 (−0.37, 0.17)	−0.21 (−0.55,0.13)
HbAlc			
Costa Rica	**0.032 (0.010, 0.055)**	−0.0014 (−0.017, 0.014)	**0.025 (0.0093, 0.040)**
+current BMI	-	−0.0091 (−0.026,0.0079)	0.013 (−0.0037, 0.029)
United States	**0.039 (0.031, 0.047)**	**0.024 (0.012, 0.036)**	**0.049 (0.041, 0.057)**
+current BMI	-	0.002 (−0.011, 0.016)	**0.043 (0.025, 0.061)**
Triglycerides			
Costa Rica	**2.2 (0.82, 3.6)**	−0.53 (−1.7,0.70)	0.18 (−0.64, 1.0)
+current BMI	-	−1.1 (−2.5, 0.37)	**−1.8 (−2.8, −0.76)**
United States	**3.2 (2.4, 4.0)**	0.20 (−1.04, 1.5)	**2.6 (1.8, 3.4)**
+current BMI	-	**−1.6 (−2.9, −0.29)**	−0.48 (−1.9, 0.90)
HDL			
Costa Rica	**−0.52 (−0.73, −0.31)**	0.00025 (−0.21,0.21)	**−0.24 (−0.40, −0.090)**
+current BMI	-	0.13 (−0.099,0.35)	0.067 (−0.12, 0.25)
United States	**−0.80 (−0.97, −0.63)**	**−0.48** (−0.64, **−0.31)**	**−0.68** (−0.83, **−0.53)**
+current BMI	-	−0.026 (−0.20, 0.15)	0.004 (−0.25, 0.25)

Table Notes:

95% confidence intervals are shown in parenthesis. Confidence intervals that do not include the null are bolded. All models contain the following additional covariates not shown: age, age squared, Hispanic (U.S. only), black (U.S. only), education (as 3 indicator variables), wealth (income in U.S.), foreign born, current smoker, physically active and Age 25 BMI. The “+ current BMI” is an identical model but additionally controls for currently measured BMI.

Table 3:

OLS Regression Models of correlation between BMI measures and current levels of biomarkers (systolic blood pressure, HbA1c, triglycerides and HDL cholesterol), Costa Rica (CRELES) and the United States (NHANES) with all measures of BMI in the same model.

	Coefficients (95% CIs) Costa Rica	Coefficients (95% CIs) United States
Systolic Blood Pressure		
current BMI	**0.47 (0.041, 0.90)**	0.26 (−0.060, 0.58)
age 25 BMI	−0.027 (−0.34, 0.28)	−0.015 (−0.30, 0.27)
maximum BMI	−0.050 (−0.47, 0.37)	−0.21 (−0.55, 0.13)
HbAlc		
current BMI	0.022 (−0.0034, 0.047)	0.007 (−0.010, 0.025)
age 25 BMI	−0.012 (−0.029, 0.0063)	−0.016 (−0.029, −0.0017)
maximum BMI	0.013 (−0.0037, 0.029)	**0.043 (0.025, 0.061)**
Triglvcerides		
current BMI	**3.8 (2.0, 5.6)**	**3.6 (2.3, 4.9)**
age 25 BMI	−0.72 (−2.2, 0.72)	**−1.4 (−2.6, −0.15)**
maximum BMI	**−1.8 (−2.8, −0.76)**	−0.48 (−1.9, 0.90)
HDL		
current BMI	**−0.59 (−0.85, −0.31)**	**−0.81 (−1.09, −0.52)**
age 25 BMI	0.11 (−0.12, 0.34)	−0.028 (−0.22, 0.16)
maximum BMI	0.067 (−0.12, 0.25)	0.004 (−0.25, 0.25)

Table Notes: 95% confidence intervals are shown in parenthesis. Confidence intervals that do not include the null are bolded. All models contain the additional covariates not shown: age, age squared, Hispanic (U.S. only), black (U.S. only), education (as 3 indicator variables), wealth (income in U.S.), foreign born, current smoker, physically active.