The mediating effects of biomarkers in the relationship between socioeconomic status and health in older populations [*]

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Palavras-chave: biomarkers, socioeconomic differences, health, aging

Resumo

Despite their long-standing interest in social inequalities in health and survival, social scientists have only recently begun to examine the underlying biological pathways linking social position to mental and physical well-being. Interest in these physiological connections has led to a proliferation of "biosocial surveys" that obtain socio-demographic information through interviews along with biological markers based on physical assessments and laboratory analyses. These markers are likely to provide researchers with more objective assessments of health status and disease than the self-reported information typically collected in household surveys and to ultimately generate insights into the causal pathways linking lower social status to poorer health outcomes. In this study, we obtain comparable estimates for three populations living in both the developed and the developing world – Costa Rica, Taiwan and the U.S. - of the mediating effects of individual biomarkers in the relationship between education and health outcomes, including self-rated health and measures of chronic conditions and functional limitations. Our results do not identify important associations between education and biomarkers of aging among near-elderly and elderly Taiwanese and Costa Rican men and women. In addition, we show that biological measures do not mediate the effects of educational attainment on self-rated health and functional limitations in both countries. In the U.S, while we find a relatively larger number of significant associations between education and biomarkers, particularly among women, the biomarkers of aging appear to mediate the relationship between SES and health deterioration at older ages only modestly, contrasting with findings from the earlier literature for western countries. Given the large discrepancies in the socioeconomic and cultural settings in the countries examined in this study, further analysis is needed to explain the underlying mechanisms behind social inequalities in health in these populations.

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Introduction

Despite their long-standing interest in social inequalities in health and survival, social scientists have only recently begun to examine the underlying biological pathways linking social position to mental and physical well-being. Interest in these physiological connections has led to a proliferation of "biosocial surveys" that obtain socio-demographic information through interviews along with biological markers based on physical assessments and laboratory analyses (Weinstein et al., 2008). These surveys are providing researchers with measurements of biomarkers related to metabolic and cardiovascular disease, often combined with indicators of immune and neuroendocrine function, for broad population-based samples. These markers are likely to provide researchers with more objective assessments of health status and disease than the self-reported information typically collected in household surveys and to ultimately generate insights into the causal pathways linking lower social status to poorer health outcomes. Although researchers are in the early stages of analyzing these biosocial surveys, the little evidence to date suggests that the patterns linking socioeconomic status (SES) to biological indicators are not systematic. That is, despite nearly ubiquitous associations between lower SES status and poorer health and survival, less educated or poorer individuals in some populations are no more likely to have "at risk" values of biological or clinical parameters than their more socially advantaged counterparts (Dowd and Goldman, 2006).

Most studies examining SES differentials in biomarkers have been based on data from wealthy Western nations, particularly the US, Canada, Great Britain, and other countries in Western Europe. We surmise that, as with SES differentials in health status, there is considerable variation in the strength of the association between health status and biological markers of stress and health across populations. In this analysis, we examine this hypothesis using data from three nationally representative surveys of older adults that incorporate an extensive set of biological measures: the Health and Retirement Survey in the US, the Costa

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Rican Study on Healthy Longevity and Aging, and the Social Environment and Biomarkers of Aging Study in Taiwan. The three nations represented by these surveys provide a fascinating set of contrasts. The US, Taiwan and Costa Rica have similarly high levels of life expectancy at birth – approximately 77 years in Taiwan, 78 in the US and 79 in Costa Rica (Population Reference Bureau, 2007). Despite this consistency in longevity, the countries have vastly different levels of economic well-being, health care expenditures and inequities in health care. Per capita income in the US is roughly nine times that of Costa Rica and almost three times that in Taiwan (Unger et al., 2008; Taiwan Economic Forum). Moreover, in contrast to the decentralized health care system in the US that leaves a large fraction of the population without health insurance or adequate health services, Taiwan and Costa Rica have national health insurance systems that cover the vast majority of residents. This health care is achieved at a fraction of the cost of health care in the US: health expenditures per capita in the US are about six times as high as in Taiwan and about nine times as high as in Costa Rica (Lu and Hsiao, 2003; Unger et al., 2008).

Background

A large body of research has examined the relationships between SES – most commonly measured by education, income, and occupational status – and clinical markers of cardiovascular and metabolic function (e.g., blood pressure, total and HDL cholesterol, body-mass index, and glucose levels). Relatively few population-based studies have examined other physiological markers related to stress and health, such as neuroendocrine and immune measures. Although there is a pervasive notion in the literature that social inequalities in health are reflected in SES differentials in biomarkers (see, for example, Kristenson et al., 2004; Siegrist and Marmot, 2004; Steptoe et al., 2002), a more nuanced assessment of empirical findings suggests that the associations between biomarkers and health status are not so clear-cut. For example, blood pressure, which is one of the most commonly analyzed biomarkers in terms of its association with SES, has been found to have an inverse association with years of schooling in some studies (Bobak et al., 1999; Martikainen et al., 2001), no significant association in others (Brunner et al., 1997; Steptoe et al., 2003) and a positive association in one study (Reddy et al., 2002). Additional evidence suggests that the relationships are likely to vary across different cultural and socioeconomic settings. For example, in a comparison of male employees in Japan and England, Martikainen et al. (2001) identified significant differences in the associations between several cardiovascular risk factors and SES between the two populations – for example, BMI and waist-hip ratio were positively related to SES in Japan, but negatively associated with SES in England.

In recent years, several population-based studies that comprise a broad biomarker collection have examined the relationship between SES and biomarkers associated with stress and health in an effort to determine the degree to which physiological measures can account for SES differentials in health status. These too have yielded conflicting results. For example, analyses based on the data from the MacArthur Studies of Successful Aging have estimated that about one third of socioeconomic differences in mortality among the elderly in the U.S. can be explained by differences in physiological dysfunction, primarily due to cardiovascular risk components and measures of immune function (Seeman et al., 2004). In contrast, a study based on data from Taiwan found that biomarkers associated with the cardiovascular, neuroendocrine, and immune systems explained little of the association between SES and health status, primarily because few biomarkers were significantly associated with education and income (Dowd and Goldman, 2006). A recent analysis of the linkages between biomarkers, health and mortality in Costa Rica suggests that the direction of the SES gradient

not only varies across biomarkers but also across different dimensions of health and survival (Rosero-Bixby and Dow, 2007).

In this study, we obtain comparable estimates for populations living in both the developed and the developing world,of the mediating effects of individual biomarkers in the relationship between education and health outcomes, including self-rated health and measures of chronic conditions and functional limitations. The findings, presented here, provide an opportunity, not yet explored in the literature, to contrast the mechanisms linking social and physical dimensions in different socioeconomic settings.

Materials and Methods

Data

Data for this analysis come from three sources: the 2000 Social Environment and Biomarkers of Aging Study (SEBAS), the Costa Rican Study on Longevity and Healthy Aging (CRELES) and the 2006 Health and Retirement Study (HRS). The SEBAS is based on a follow-up of the Survey of Health and Living Status of the Near Elderly and Elderly in Taiwan, a nationally representative longitudinal survey (including the institutionalized population) that was administered four times between 1989 and 1999. The initial survey consisted of 4,049 eligible respondents who were aged 60 years and older in 1989. In 1996, the study added a new cohort of 2,462 near-elderly respondents who were aged 50 to 66 years in 1996. The two cohorts were interviewed again in 1999. In 2000, a subsample of respondents for SEBAS were drawn randomly from the combined near-elderly and elderly cohorts who were surviving in 1999. Persons aged 70 years and older in 1999 and persons in urban areas were oversampled. SEBAS consists of two parts: a face-to-face in-home interview and a medical exam. Among the 1,713 respondents selected for this study, a total of 1,497 answered face-to-face in-home interviews (a response rate of 92 percent among survivors). The interviews comprise information regarding demographic and socioeconomic characteristics, physical health, health-related behaviors, psychological well-being and health service utilization. Respondents were interviewed in their homes between July and December 2000.

Among the 1,497 participants who completed in-home interviews, 1,023 participated in the medical examinations (68% of those interviewed). Disproportionately high non-participation rates were found among the healthiest respondents as well as the least healthy, with persons who received the medical exam reporting the same average health status as those who did not. Results presented elsewhere suggest that, in the presence of controls for age, estimates from the medical exam portion of SEBAS are unlikely to be seriously biased.

SEBAS respondents collected a 12-hour urine specimen overnight and accompanied a member of the Bureau of Health Promotion in Taiwan to a hospital visit the following morning. During the hospital visit, respondents provided a spot urine sample and a fasting blood sample, and staff members measured the respondents' waist and hip circumference, height, weight, and blood pressure. The clinical data provided biological markers that are comparable to those collected in recent surveys in the U.S (Seeman et al. 1997; Singer and Ryff 1999).

The CRELES is an on-going longitudinal study of a nationally representative sample of 3,000 adults born in 1945 or before (ages 60 and over at the first interview) and residing in Costa Rica in the year 2000, with over-sampling of the older old. For this analysis we use the data

for the first wave of interviews, conducted in 2004. A sample of 9,600 individuals was randomly selected from the 2000 census database after stratification by 5-year age groups. Sampling fractions ranged from 1.1% among those born in 1941-45 to 100% for the born before 1905. This sub-sample included near 5,300 individuals and covers 59% of Costa Rican territory, yielding the following non-response rates: 19% of the individuals deceased by the contact date, 18% were not found in the field, 2% moved to other addresses, 2% rejected the interview, and 2% remained as pendant interviews after several visits (likely rejections). Among those interviewed, 95% of the participants provided blood sample, 92% collected urine, 91% had anthropometric measures, and 24% required a proxy to answer the questionnaire.

The data and specimens in the CRELES study were collected at the participants' homes, usually in two visits. In the first visit, participants provided informed consent and answered a 90-minute long questionnaire (including some mobility tests and two blood-pressure measures) as well as a 10-minute frequency of tracer food consumption questionnaire. In a second visit early the next day, fasting blood samples were collected by venipuncture: 1 EDTA purple top tube (for 3-4 ml. of whole blood) and 2 serum separating tubes (SST), with a clot activator (for 10-12 ml. of blood, to obtain 4-6 ml. of serum). In this visit, the field team also picked up a cooler containing 12-hour overnight urine and took the anthropometric measures. All field data were collected using Personal Digital Assistants (PDAs), also known as palm computers, with software applications developed by CCP for this study.

The HRS started in 1992 as nationally representative study of the non-institutionalized population aged 51 to 61 and their spouses/partners (regardless of age). The initial sample consisted of 15,497 eligible respondents of which 12,654 answered the interviews: 9,824 cohort-eligible respondents and 2,830 spouses. Subsequently this survey was merged with the Study of Assets and health Dynamics among the Oldest Old (AHEAD), a national panel study of 7,446 Americans age 70 and older in 1993 and their spouses/partners (regardless of age). Latter, the data collection effort added two other cohort-eligible respondents: i) a War Babies sample of people born in 1942-1947 and their spouses (regardless of age); and ii) the Children of the Depression Age - a sample of people born in 1924-1930 (who did not have a spouse who was born before 1924 or between 1931 and 1947). These four cohorts and their spouses/partners were interviewed every two years, from 1998 to 2002. In 2004, a new cohort was added to the study, the Early Boomers, which includes people born between 1948 and 1953 and their spouses/partners (regardless of age). All cohorts were interviewed again in 2004 and 2006. The HRS includes a very comprehensive set of questions on health, work and retirement, income and wealth, as well as family and demographic characteristics.

In the 2006 HRS wave, 18,409 people answered the core interview. In addition, from the original sample, a one-half random sub-sample was pre-selected to provide an enhanced face-to-face interview on physical health and to supply biomarkers measurements. Among these measures many are comparable to those collected in CRELES and SEBAS, which allowed us to add estimates for the U.S. in our analysis. Prior to collect the data, individuals had to provide written consent for the interviewer and received information about how the measures would be administered. Individuals who did not feel safe about the collection procedures were allowed not to participate. The data and specimens were collected at the participants' homes. After completing the enhanced health questionnaires, individuals were asked to provide i) a saliva sample collected by swishing a small quantity (10 ml) of Scope mouthwash for about 45 seconds and spitting the contents into a container that was sealed and packaged, and ii) a small quantity of blood via finger prick. Three measurements of blood pressure were also taken, every 45 seconds, using an automated device, and for respondents weighting less than

300 pounds and who were able to stand, weight was measured with a scale. In addition, waist circumference and height - measured with the respondents standing against a wall without shoes - were both measured with a tape measure.

Variables

Population-based studies on the biology of stress have used physiological markers pertaining to the cardiovascular, metabolic, immune, and neuroendocrine systems. In order to preserve comparability across populations, we limit the analysis in this article to biomarkers that were ascertained in all three surveys, or at least, that were collected in both SEBAS and CRELES, surveys that have a somewhat larger array of markers available than the HRS. Out of the ten markers examined in this study, eight are measures of the metabolic syndrome and two are measures of the neuroendocrine system: urinary cortisol and DHEAS. Whenever clinical cutoff values for biomarkers are available, we use these cutoff points to construct dichotomous variables for the given marker, coded as 1 when the respondent has a high risk value and 0 otherwise (see Table 1).

Among markers for the metabolic syndrome, we include two indicators of body fatness: BMI and waist circumference. BMI, calculated as weight divided by height squared (Kg/m^2), is recoded into a dichotomous variable that takes the value of one for respondents who have values larger than 30 and lower than 18.5. To look at the effects of waist circumference, we code values larger than 88 centimeters for women and 102 for men as high risk. Two markers for hypertension – systolic and diastolic blood pressure – are coded as dichotomous variables that take the value of one for respondents who have values larger than 140 and 90 mmHg respectively. We include measures of total serum cholesterol (risk values larger than or equal to 250 mg/dL) and triglycerides (risk values larger than 200 mg/dL), taken from blood specimens. Two biomarkers relate to glucose metabolism – fasting glucose and glycosylated hemoglobin (HbA_{1c}). Cutoff values for these measures are 100 mg/dl and 6.5 mmol/L, respectively.

In the absence of guidelines for normal ranges of nonclinical markers, we use cut points for cortisol and DHEAS that are based on the distribution of these biomarkers in the surveys. These biomarkers take the value 1 for respondents who have values in the lowest quartile (DHEAS) and in the lowest or highest deciles (cortisol), with the cutoff points calculated separately for men and women. Triglycerides, fasting glucose, cortisol and DHEAS are not available in the HRS, and therefore, are compared only in SEBAS and CRELES.

Health outcomes comprise three measures. We use self-rated health, reported according to the conventional 5-point ordinal scale: excellent, very good, good, fair and poor. We also include self-reports of chronic conditions and functional limitations that are comparable in all surveys and that have been shown to reflect health deterioration at older ages. Chronic conditions are recorded as a count of seven common serious conditions: high blood pressure, diabetes, cancer or malignant tumor, chronic respiratory diseases, heart problems, stroke, and cataracts in the eye (except for the HRS). Functional limitations are based on self-reports of four mobility limitations (lifting or carrying weight, raising arms above shoulders, walking many blocks and climbing stairs), two measures of instrumental activities of daily living (buying personal items and managing money), and three measures of activities of daily living (bathing, eating, and toileting).

Our analysis presented here includes only education as a measure of socioeconomic status (SES) because it provides the easiest to collect and most consistent measure of SES across the three populations. Also, to preserve further comparability, we code education into three-categories, according, approximately, to the terciles of its distribution in each survey. In Taiwan and Costa Rica the cutoff points, respectively for men and women, are fairly comparable: 0-5, 6, 7+ and 0, 1-6, 7+ years of education in Taiwan; and 0-1, 2-5, 6+ and 0-2, 3-5, 6+ years of education in Costa Rica. In the U.S., where education has been mandatory for both sexes over a longer period of time, the cutoff points used are somewhat different from those for the other two countries: 0-12 12, and 13+ years of education for both sexes. Finally, while the age range is similar across the surveys' samples (54 and over in Taiwan, 60 and over in Costa Rica, and 53 and over in the U.S.), we include linear and quadratic controls for age in all models.

Analytic Strategy

To examine the associations between education and the physiological measures, we estimate, for each population, separate logistic regression models for each biomarker, controlling for age and educational attainment. We fit separate models for men and women because of sex differences in the biological mechanisms linking socioeconomic status and health (Dowd and Goldman 2006).

To test for the mediating effects of biomarkers in the relation between education and health, we estimate sex-specific models separately for Costa Rica, Taiwan and the U.S. Ordered logistic regression models are used for self-rated health, and Poisson regression models for the counts of functional limitations and of chronic conditions. We compare two models for each health outcome. The first one controls only for age and education. In the second model, we add the individual biomarkers to the first model.

In each survey we use alternative strategies to account for the different multi-stage sampling designs employed during data collection. In the case of SEBAS, we add a dummy variable for urban residence, and adjust for clustering by primary sampling units (PSUs) to produce correct standard errors. In CRELES and in the HRS, we use weighed data. We use Stata 8.2 to estimate the models (StataCorp 2003).

RESULTS

Table 1 displays the cutoff points and summary measures for high risk values of individual markers in each country. Although the results are not weighted, they suggest, not surprisingly, higher proportions of BMI and waist circumference risky cases in the U.S compared to Taiwan and Costa Rica. In addition, Costa Rica appears to present higher proportions of cases with high risk values of blood pressure and cholesterol than the other two countries.

Estimated coefficients for education from the logistic models of having high risk values of each biomarker are presented on Tables 2 to 4. Except for BMI and DHEAS (both sexes), and diastolic blood pressure and glucose (women), we find no other statistically significant associations between education and the physiological measures in Taiwan (Table 2). These

results are consistent with previous analyses based on the Taiwan data but with a somewhat different set of biomarkers and cutoff points (Dowd and Goldman 2006). The number of significant associations between education and the probability of having high risk values of the biomarkers is also modest in Costa Rica, although we find statistically significant associations with BMI, DHEAS and triglycerides values among men, and systolic blood pressure, waist circumference and glycosylated hemoglobin among women (Table 3). In contrast, in the U.S., while the list of biomarkers being examined is shorter than for the other two countries, we find, except for cholesterol, statistically significant associations between education and all the measures used among women. Among men, the number of statistically significant associations is, however, also modest: only systolic blood pressure and glycosylated hemoglobin are significantly associated with education.

Education is related to self-rated and functional limitations health outcomes in Taiwan and Costa Rica (Tables 5 and 6), but we find no evidence that physiological measures of stress strongly mediate the relationship between education and health in these countries. That is, the coefficients on the education variables change relatively little with the inclusion of the biomarkers in the second model. This finding is particularly true for Costa Rica. In addition, with the exception of the model for functional limitations among women in Taiwan, there are no changes in the significance of the coefficients for education in any of the models presented in Tables 4 and 5, after the inclusion of the biomarkers.

In the U.S., in addition to self-rated health and functional limitations, education is also statistically significantly associated with chronic conditions among women (Table 7). But despite the larger number of statistically significant associations found between education and the biomarkers, particularly among women, the physiological measures of stress also seem not to mediate the relationship between education and self-rated health and functional limitations in the U.S., after the inclusion of the biomarkers. Coefficients for chronic conditions change relatively more among women in the second model– between one third and one half – but much of the effect of the education variables on chronic conditions remain to be explained.

In models not presented here, we explored the robustness of these findings by using other specifications for educational attainment (based on education levels rather than terciles) and a single measure of age (only a linear term). The alternative formulations produced results similar to those described above.

DISCUSSION

This study has extended a growing body of research on the pathways linking socioeconomic status and health status by examining the role of a broad set of biomarkers as mediating effects in the relation between education and self-reported measures of health among three older populations in very different socioeconomic settings: Taiwan, Costa Rica and the U.S. These markers include both clinical measures that are part of routine medical exams and physiological parameters that are not commonly evaluated and for which there are clinical thresholds.

Our results did not identify important associations between education and biomarkers of aging among near-elderly and elderly Taiwanese and Costa Rican men and women. Our analysis

further suggests that these biological measures do not mediate the effects of educational attainment on self-rated health and functional limitations in both countries. Our findings appear to be inconsistent with results from studies of aging conducted in developed western countries. Those studies suggest that biological mechanisms similar to those measured in the present analysis are potential pathways through which socioeconomic status is likely to affect health deterioration at older ages. In fact, we also found a relatively larger number of significant associations between education and biomarkers in the U.S. than in Costa Rica and Taiwan. But in contrast to previous studies that used data from community based surveys, our analysis, which is based on a nationally representative survey of the American elderly population, showed that these associations are substantial only among women. In addition, except for chronic conditions and the models for women, biomarkers did not appear to mediate the relationship between SES and health deterioration at older ages in the U.S. as strong as suggested in the earlier literature.

Thus, despite the large discrepancies in the socioeconomic and cultural settings in the countries examined in this study, our results did not point to marked differences in the mediating role played by the biomarkers across the three populations. Further studies of this kind should help scientists to elucidate the underlying mechanisms behind social inequalities in health. Much remains to be learned on why health inequalities vary across different populations.

REFERENCES

Bobak, M. et al. 1999. Socioeconomic status and cardiovascular risk factors in the Czech Republic. *International Journal of Epidemiology*, 28:46-52

Brunner, E. 1997. Stress and the biology of inequality. *British Medical Journal*, 314:1472-76.

Dowd, J.B. and N. Goldman. 2006. Do biomarkers of stress mediate the relation between socioeconomic status and health? *Journal of Epidemiology and Community Health*, 60:633-639.

Kristenson, M. et al. 2004. Psychobiological mechanisms of socioeconomic differences in health. *Social Science & Medicine*, 58:1511-1522.

Lu, J-F.R. and W.C. Hsiao. 2003. Does universal health insurance make health care unaffordable? Lessons from Taiwan. *Health Affairs*, 22:77-88.

Martikainen, P. et al. 2001. Socioeconomic differences in behavioural and biological risk factors: a comparison of a Japanese and an English cohort of employed men. *International Journal of Epidemiology*, 30:833-848.

Population Reference Bureau. 2007 Data Sheet. http://www.prb.org/Publications/Datasheets/2007/2007WorldPopulationDataSheet.aspx

Reddy, K.K.R. et al. 2002. Socioeconomic status and the prevalence of coronary heart disease risk factors. *Asia Pacific Journal of Clinical Nutrition*, 11:98-103.

Rosero, L. and W. Dow. 2007. The puzzling SES gradients in adult health and mortality of a Latin American population. Paper presented at the 2007 annual meeting of the Population Association of America, New York City, March 29-31

Seeman, T.E., B.H. Singer, J.W. Rowe, R.I. Horwitz, and B.S. McEwen. 1997. "Price of adaptation - Allostatic load and its health consequences - MacArthur studies of successful aging." *Archives of Internal Medicine* 157(19):2259-2268

Seeman, T.E. et al. 2004. Cumulative biological risk and socio-economic differences in mortality: MacArthur studies of successful aging. *Social Science & Medicine*, 58:1985-1997.

Singer, B., & Ryff, C.D. (1999). Hierarchies of life histories and associated health risks. *Annals of the New York Academy of Sciences*, 896, 96-115.

StataCorp. 2003. *Stata Statistical Software: Release 8.0.* College Station, TX: Stata Corporation.

Siegrist, J. and M. Marmot. 2004. Health inequalities and the psychosocial environment-two scientific challenges. *Social Science & Medicine*, 58:1463-1473.

Steptoe, A. and M. Marmot. 2002. The role of psychobiological pathways in socio-economic inequalities in cardiovascular disease risk. *European Heart Journal*, 23:13-25.

Steptoe, A. et al. 2003. Socioeconomic status and stress-related biological responses over the working day. *Psychosomatic Medicine*, 65:461-470.

Taiwan Economic Forum (TEF). *EIU Country Data [Online]*. Available: Economist Intelligence Unit. http://www.eiu.com/index.asp?layout=VWCountryVW3&region_id=&country_id=1630000163

Unger, J-P. et al. 2008. Costa Rica: Achievements of a heterodox health policy. *American Journal of Public Health*, 98:636-643.

Weinstein, M., J.W. Vaupel and K.W. Wachter, editors. 2008. *Biosocial Surveys*. Committee on advances in collecting and utilizing biological indicators and genetic information in social science surveys. Washington, DC: National Academies Press.

Table 1 . Cutt off points and summary measures for high risk values of individual biomarkers in Sebas (2000), Creles (2004-2006) & HRS (2006)

Sex/Biomarker	Cutoff points for high risk values	SEBAS Sample Size	SEBAS Proportion of high risk cases	CRELES Sample Size	CRELES Proportion of high risk cases	HRS Sample Size	HRS Proportion of high risk cases
Women							
BMI (Kg/m^2)	>30 or <18.5	433	0.13	1463	0.28	2981	0.39
Waist Circumference (cm)	>88	433	0.29	1421	0.61	3049	0.71
Glucose (mg/dl)	>100	332	0.48	1439	0.50	N/A	
HbA_{1c} (mmol/L)	≥6.5	338	0.23	1431	0.14	2731	0.12
Systolic Blood Pressure (mmHg)	>140	339	0.49	1515	0.57	3086	0.32
Diastolic Blood Pressure (mmHg)	>90	339	0.20	1515	0.27	3086	0.17
Cholesterol (mg/dL)	≥250	339	0.15	1448	0.28	2598	0.12
Triglycerides (mg/dL)	≥200	339	0.12	1447	0.22	N/A	
DHEAS (µg/dl)	<29.2 (Sebas)	339	0.28			N/A	
	<15.1(Creles)			1426	0.25		
Cortisol (µg/g creatinine)	<10.06 or >53.61 (Sebas)	337	0.20			N/A	
	<9.86 or >56.19 (Creles)			1209	0.20		
Men							
BMI (Kg/m^2)	>30 or <18.5	589	0.09	1235	0.15	2205	0.37
Waist Circumference (cm)	>102	590	0.04	1211	0.18	2279	0.56
Glucose (mg/dl)	>100	573	0.34	1206	0.39	N/A	
HbA_{1c} (mmol/L)	≥6.5	589	0.10	1185	0.09	1969	0.14
Systolic Blood Pressure (mmHg)	>140	590	0.40	1278	0.53	2293	0.38
Diastolic Blood Pressure (mmHg)	>90	590	0.19	1278	0.24	2293	0.18
Cholesterol (mg/dL)	≥250	589	0.08	1209	0.14	1856	0.07
Triglycerides (mg/dL)	≥200	589	0.10	1209	0.20	N/A	
DHEAS (µg/dl)	<53.5 (Sebas)	588	0.25			N/A	
	<29.3(Creles)			1192	0.25		
Cortisol (µg/g creatinine)	<8.76 or >48.32 (Sebas)	588	0.20			N/A	
	<7.86 or >43.04 (Creles)			1041	0.20		

Table 2 - Estimated Coefficients from logistic models of having high risk values of each biomarker, by education and sex. SEBAS, 2000

	BMI	Waist Circumference	Systolic BP	Diastolic BP	Glucose	HbA1c	Cholesterol	Triglycerides	DHEAS	Cortisol
Men										
1st tercile (omitted)										
2nd tercile of education	-0.5480*	-0.2184	0.0668	-0.1176	0.406	-0.0395	-0.0856	-0.4887	0.0000	-0.2499
	[0.2677]	[0.4744]	[0.1684]	[0.2895]	[0.3330]	[0.2819]	[0.4331]	[0.3188]	[0.2427]	[0.1820]
3rd tercile of education	-0.4648	-0.3497	-0.2153	-0.3481	0.6944**	0.0919	-0.458	-0.4423	-1.0834**	-0.2089
	[0.3327]	[0.5785]	[0.1870]	[0.3136]	[0.2577]	[0.3147]	[0.3700]	[0.3883]	[0.2169]	[0.2631]
Number of observations	589	590	590	590	573	589	589	589	588	588
Women										
1st tercile (omitted)										
2nd tercile of education	0.2627	0.2434	-0.0543	-0.0547	-0.0528	-0.3517	-0.2855	-0.1491	-0.1529	0.2575
	[0.2446]	[0.1937]	[0.2204]	[0.2489]	[0.2234]	[0.3205]	[0.2398]	[0.3807]	[0.2325]	[0.2585]
3rd tercile of education	-2.1922*	-0.5982	-0.2185	-1.1564*	-0.2787	-0.3629	-0.0964	0.7828	-2.0360*	-0.8499
	[0.9876]	[0.3318]	[0.3325]	[0.5092]	[0.3443]	[0.4425]	[0.4716]	[0.4177]	[0.8519]	[0.5186]
Number of observations	433	433	433	433	424	432	433	433	433	431

All models control for urban condition and linear and quadratic terms for age.
Standard errors in brackets
* significant at 5%; ** significant at 1%

Table 3 - Estimated Coefficients from logistic models of of having high risk values of each biomarker, by education and sex. CRELES, 2004-2006

	BMI	Waist Circumference	Systolic BP	Diastolic BP	Glucose	HbA1c	Cholesterol	Triglycerides	DHEAS	Cortisol
Men										
1st tercile (omitted)										
2nd tercile of education	0.0901	0.0382	0.0181	-0.2053	0.0359	0.3233	0.1019	0.3257	0.1682	-0.3086
	[0.2432]	[0.2134]	[0.1616]	[0.1815]	[0.1680]	[0.3001]	[0.2215]	[0.2040]	[0.2219]	[0.2190]
3rd tercile of education	0.6237**	0.3724	-0.2052	-0.1492	0.2628	0.2124	-0.1523	0.3785*	0.5057*	-0.0687
	[0.2174]	[0.1936]	[0.1497]	[0.1657]	[0.1560]	[0.2848]	[0.2117]	[0.1900]	[0.2105]	[0.2001]
Number of observations	1288	1279	1334	1334	1258	1239	1268	1268	1250	1117
Women										
1st tercile (omitted)										
2nd tercile of education	-0.1413	-0.2353	0.1493	0.2299	0.2699	-0.2114	0.0768	-0.1737	-0.0792	0.1197
	[0.1642]	[0.1576]	[0.1469]	[0.1559]	[0.1481]	[0.1937]	[0.1598]	[0.1740]	[0.1880]	[0.2090]
3rd tercile of education	0.0491	-0.3438*	-0.3342**	-0.1797	0.1049	-0.7086**	-0.0764	-0.1024	0.2673	0.3397
	[0.1399]	[0.1381]	[0.1263]	[0.1398]	[0.1291]	[0.1780]	[0.1408]	[0.1493]	[0.1615]	[0.1810]
Number of observations	1415	1398	1473	1473	1394	1389	1404	1403	1377	1204

All models are weighed and control for linear and quadratic terms for age.
Standard errors in brackets
* significant at 5%; ** significant at 1%

Table 4 - Estimated Coefficients from logistic models of of having high risk values of each biomarker, by education and sex. HRS, 2006

	BMI	Waist Circumference	Systolic BP	Diastolic BP	HbA1c	Cholesterol
Men						
1st tercile (omitted)						
2nd tercile of education	-0.0174	-0.0115	-0.1394	-0.0356	-0.2534	0.1031
	[0.1348]	[0.1287]	[0.1298]	[0.1616]	[0.1812]	[0.2743]
3rd tercile of education	-0.0824	-0.125	-0.2522*	-0.2155	-0.4966**	-0.265
	[0.1251]	[0.1180]	[0.1207]	[0.1507]	[0.1744]	[0.2590]
Number of observations	2817	2919	2931	2931	2506	2368
Women						
1st tercile (omitted)						
2nd tercile of education	-0.2018	-0.3002*	-0.2980**	-0.2813*	-0.5982**	0.0306
	[0.1045]	[0.1182]	[0.1077]	[0.1242]	[0.1467]	[0.1639]
3rd tercile of education	-0.5747**	-0.6351**	-0.4993**	-0.3897**	1.0270**	-0.1851
	[0.1056]	[0.1141]	[0.1095]	[0.1258]	[0.1599]	[0.1663]
Number of observations	3799	3897	3955	3955	3509	3348

All models are weighed and control for linear and quadratic terms for age.
Standard errors in brackets
* significant at 5%; ** significant at 1%

Table 5 - Estimated regression coefficients for three health outcomes, by education and sex. SEBAS, 2000

	Men			Women		
	Self Rated Health	Functional Limitations	Chronic Conditions	Self Rated Health	Functional Limitations	Chronic Conditions
Model 1						
1st tercile (omitted)						
2nd tercile of education	-0.1342	-0.6062**	-0.147	-0.4122	-0.4636*	-0.0975
	[0.1908]	[0.2305]	[0.0976]	[0.2630]	[0.2064]	[0.1093]
3rd tercile of education	-0.6030*	-0.6954*	-0.0482	-0.9457**	-0.4510*	0.0108
	[0.2476]	[0.2728]	[0.1096]	[0.2784]	[0.1834]	[0.0991]
Model 2						
1st tercile (omitted)						
2nd tercile of education	-0.1266	-0.5324**	-0.1706	-0.4189	-0.4276*	-0.105
	[0.1925]	[0.2013]	[0.0891]	[0.2654]	[0.1856]	[0.0980]
3rd tercile of education	-0.5410*	-0.5549*	-0.0797	-0.7814**	-0.2893	0.0146
	[0.2323]	[0.2326]	[0.0951]	[0.2934]	[0.1936]	[0.0935]
Number of observations	569	569	565	421	419	417

Model 1 controls for urban condition and linear and quadratic terms for age. Model 2 controls for urban condition, linear and quadratic terms for age and ten biomarkers: BMI, waist circumference, systolic blood pressure, diastolic blood pressure, fasting glucose, HbA1c, total cholesterol, triglycerides, DHEAS and cortisol

Standard errors in brackets

* significant at 5%; ** significant at 1%

Table 6 - Estimated regression coefficients for three health outcomes, by education and sex. CRELES, 2004-2006

	Men			Women		
	Self Rated Health	Functional Limitations	Chronic Conditions	Self Rated Health	Functional Limitations	Chronic Conditions
Model 1						
1st tercile (omitted)						
2nd tercile of education	-0.1952	-0.0603	0.1118	-0.2623	-0.2674**	-0.0014
	[0.1709]	[0.0762]	[0.0813]	[0.1556]	[0.0607]	[0.0642]
3rd tercile of education	-1.1101**	-0.4546**	-0.0185	-1.0236**	-0.4941**	-0.0826
	[0.1614]	[0.0799]	[0.0793]	[0.1371]	[0.0562]	[0.0578]
Model 2						
1st tercile (omitted)						
2nd tercile of education	-0.2188	-0.0634	0.0784	-0.2358	-0.2178**	0.003
	[0.1721]	[0.0765]	[0.0817]	[0.1567]	[0.0612]	[0.0646]
3rd tercile of education	-1.1325**	-0.4898**	-0.0655	-1.0219**	-0.4874**	-0.0465
	[0.1627]	[0.0804]	[0.0798]	[0.1388]	[0.0567]	[0.0584]
Number of observations	1020	843	904	1116	936	1072

Model 1 controls linear and quadratic terms for age. Model 2 controls for linear and quadratic terms for age and ten biomarkers: BMI, waist circumference, systolic blood pressure, diastolic blood pressure, fasting glucose, HbA1c, total cholesterol, triglycerides, DHEAS and cortisol. All models are weighted.
Standard errors in brackets
* significant at 5%; ** significant at 1%

Table 7 - Estimated regression coefficients for three health outcomes, by education and sex. HRS, 2006

	Men			Women		
	Self Rated Health	Functional Limitations	Chronic Conditions	Self Rated Health	Functional Limitations	Chronic Conditions
Model 1						
1st tercile (omitted)						
2nd tercile of education	-0.7168**	-0.3520**	-0.0408	-1.0673**	-0.4311**	-0.1828**
	[0.1410]	[0.0955]	[0.0563]	[0.1126]	[0.0507]	[0.0434]
3rd tercile of education	-1.2596**	-0.6758**	-0.1019	-1.5674**	-0.6066**	-0.3065**
	[0.1380]	[0.0973]	[0.0519]	[0.1163]	[0.0652]	[0.0457]
Model 2						
1st tercile (omitted)						
2nd tercile of education	-0.7026**	-0.3556**	-0,0253	-0.9895**	-0.3656**	-0.1092**
	[0.1433]	[0.0949]	[0.0541]	[0.1135]	[0.0553]	[0.0408]
3rd tercile of education	-1.2233**	-0.6653**	-0,0713	-1.438**	-0.4960**	-0.1910**
	[0.1352]	[0.0967]	[0.0515]	[0.1176]	[0.0631]	[0.0430]
Number of observations	2203	2200	2197	3037	3033	3026

Model 1 controls linear and quadratic terms for age. Model 2 controls for linear and quadratic terms for age and ten biomarkers: BMI, waist circumference, systolic blood pressure, diastolic blood pressure, HbA1c, and total cholesterol. All models are weighted.
Standard errors in brackets
* significant at 5%; ** significant at 1%