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Spatial Correlates of U.S. Heights and BMIs, 2002

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Abstract

Aiming to further explore possible underlying causes for the recent stagnation in American heights, this paper describes the result of analysis of the commercial U.S. Sizing Survey. Using zip codes available in the data set, we consider geographic correlates of height such as local poverty rate, median income, and population density. We find that after adjusting for variables known to influence height such as income and education, population density is negatively correlated with height among white men, but only marginally among white women. Similar analysis of Body Mass Index (BMI) also shows a negative correlation with population density after adjustment for income, education, and age for both sexes. Local economic conditions as measured by median income, unemployment rate or poverty rate do not have a strong correlation with height or weight after adjusting for individual income and education.

Key words: Height, Biological Standard of Living, Anthropometry, Social inequality, Health, Physical Stature, BMI, Weight

JEL Classification: D60, I10, I31, J15

Introduction

Why have the heights of Americans, the tallest in the world until the latter half of the 20th century, stagnated while those of Western- and Northern Europe have increased substantially? European heights generally surpassed American heights in the 1970s and 80s and the mean height difference is currently circa 2-6cm (Fredriks 2000; Sunder 2003). Not merely a question for anthropometricians, this is an issue of broad interest as the mean height of populations often reflect differences in health and longevity. It is well documented that early life nutrition and disease are the major environmental influences on terminal height (Costa, 1993; Komlos and Cuff 1998; Komlos and Baten 1999; Waaler, 1984). However, the disparity in height between Europe and North America has been challenging to explain in those terms, given the increasing economic prosperity experienced on both sides of the Atlantic.

While the income gradient in self-reported health is larger in the U.S. than in Canada (which has universal health insurance), the gap is smaller for the elderly, who are covered by universal health insurance in both countries (Decker and Remler, 2004). Similarly, Germans evaluate their own health status more positively than Americans do (Komlos and Baur 2004). Moreover, Swedish life expectancy exceeds that of the US by 1.9 years (Human Development Report 2000, p. 157). Such findings, as well as the divergence in height, and increasing obesity in the U.S. all indicate that different political choices regarding health care distribution and/or individual choices regarding consumption might be the cause of stagnation in American height (Komlos, Smith and Bogin 2004). In developed societies where caloric and protein intake is rarely limited by family income, height reflects less the economic output of a community and more its political and social choices that influence overall health during childhood development. This observed discrepancy between material welfare and biological well-being has helped to motivate the development of a distinct concept of a biological standard of living.

This paper examines spatial patterns in height and bmi in the U.S. in the hope of shedding light on this conundrum. Because there are broad demographic differences between the U.S. and Europe, it may be possible to explain the height discrepancy by linking height to demographic factors within the US. Thus, in addition to using the usual control variables own income and education, we examine the effect of such variables at the community level as population density, median income, unemployment rate, and poverty rate on height and BMI. These local environmental factors offer the opportunity for better describing gradients in American height as well as an avenue for analyzing differences between the U.S. and Europe in the future.

The Sizing Survey Data

The U.S. Sizing Survey (SizeUSA CD-ROM) was organized by a clothing industry trade group in 2002 with funding from a number of U.S. clothing manufacturers and the U.S. Army and Navy to provide data on the distribution of body size and body proportions in the U.S. population for the purposes of creating better fitting off-the-shelf clothing. As such, it contains a large number of variables on various body measurements relevant for clothing manufacturing.[1] The sample of 10,000 individuals (3,689 male, 6,311 female; 18 and older) was drawn from shoppers at a series of shopping centers around the country, in 13 geographic clusters.[2] Heights were measured to the nearest half-inch and weights to the nearest pound. The socio-economic data is reported categorically for income, education, age, and race/ethnicity. The number of individuals in each location varies widely, from 1,748 individuals in Dallas (73% of whom were female) to just 97 in Miami. This sampling procedure precludes making strong claims about the general U.S. population as in the NHANES 1999-2002 survey (Table 1), which claims to be representative of the U.S. population. BMIs are much lower among the survey population than in the NHANES sample, which may indicate that collecting survey data in shopping centers introduces systematic bias insofar as it samples from the more active part of the population with lower BMI.[3]

Insert Table 1 about here

The question of whether to adjust for measurement site is a difficult one since the very different conditions around each site make this a choice between under-adjusting and over-adjusting: each cluster may capture a different segment of the US population. Consequently, the results with and without this adjustment are discussed below on a case-by-case basis, though it should be noted immediately that there are only two differences in height or BMI between the different sites that are statistically significant at the 95% level.

To explore the relationship between local environment and individual height and weight, the zip codes in the data were linked to summery data from the U.S. 2000 census compiled by Zip Code Tabulation Area (ZCTA).[4] As height is correlated with socio-economic status in the United States as everywhere else (Komlos and Kriwy, 2003) we adjust for those variables as well as the age groupings in all reported analysis. Ethnicity is categorized as White, Black, Hispanic, and Other, but we only use those records in the sample whose ethnicity category is "White". Blacks were not considered because the sample is too small (627 Men and 989 Women) to achieve statistical significance on any examined variables when analyzed separately from whites. We decided not to combine the white and black populations because of the high levels of persistent residential segregation in the U.S. make the assumption that blacks and whites respond similarly to the influences of local environment unjustified. The other two groups, “Hispanic” and “Other”, were excluded from the analysis because of their greatly increased chance of being foreign born. We also excluded everyone in the 66+ group.[5] These eliminations left 1,524 men and 2,903 women in the sample. There is no explicit variable for being U.S. born, however given that only 14% of current U.S. foreign-born individuals originated in Europe while 53% originated in Latin America and 25% in Asia and that foreign born individuals comprise 12% of the U.S. population (U.S. Census Current Population Survey, 2003), most immigrants should be identified as “Hispanic” or “Other”.

Individual Predictors of Height and Weight

Both men and women exhibit an increase in height with higher income and educational attainment (Table 2).[6] Recent increases in height have been slight since the birth cohorts of 1957-66: about 0.5 inches for both males and females.[7] While the age and education effects on the height of men and women are similar, the income coefficient is larger for men than for women, a result not previously observed (Komlos and Baur, 2004). This disparity may reflect the fact that household incomes are reported in this sample. Since the incomes of men are more influential in determining household incomes—due to their higher individual incomes and higher rates of work—the weaker correlation between height and income for women is expected. Alternatively, greater individual height may lead to greater income (Heineck, 2004), which may be a stronger effect for men than for women given their greater mean income.

Tables 2 and 3 about here

In contrast to the height data, for which there is slightly greater variance among men, for weight the variance is much greater for women; this is reflected in differences between education, income and age groups (Table 3). We find the increase in BMI for both men and women with age is large and monotonic up the 46-55 age group: men’s BMI increases by 3.9 from the 18-25 group to the 46-55 group while women’s BMI increases by 4.6 over that range.

Men's BMIs show no significant correlation with income, however women's BMI's appear to have two levels, with the three income groups below $75,000/year having 1.4 greater BMI than the two above that threshold. With respect to education, men again show no significant correlations with BMI. Among women, generally greater education is correlated with lower BMI, as in other samples (Komlos and Baur 2004).

Local Environmental Predictors: Population Density

When looking at quantitative measures of local conditions, population density is an appealing metric because density differences can indicate differences in how people live in different communities. Higher density communities are likely to have more immediately available health services and people may spend less time in cars, but may also have lower rates of voluntary exercise, higher stress and greater environmental pollution. Since the population densities in the sample population range from less than 100 per square mile to 100,000 per square mile, we used a log transform on population density (Figure 1).[8] The population density distribution of our data is similar to that of the U.S. population as a whole, although the mean is almost twice as high[9] because the rural areas (<150 people per square mile) are under-sampled and moderate density areas (150-3000 people per square mile) are over-sampled. The data are sufficiently plentiful to analyze over the range of densities from e^{4} to e^{11}. The overall population density of the United States is 80 ($e^{4.4}$) persons per square mile versus 320 ($e^{5.8}$) in the European Union, however these figures include all land area (including uninhabitable land area) and are not directly comparable to the figures obtained for zip codes.[10]

Insert Figure 1 and Table 4 about here

Height is much more strongly correlated with population density for men than it is for women. For men, after adjustment for individual income and education, an increase in population density by a factor of e corresponds to a change in height of -0.25 (+/- 0.10, p=0.00001) (Table 4). The relationship between height and density is linear over the range where there are sufficient data to estimate a mean height as a function of density (Figure 2). The difference in height over the range from densities in the data (e^4 to e^{11}) is 1.75 inches (4.5 cm), a very large difference for population mean height.[11]

Insert Figures 2 and 3 about here

Using a similar linear model for women, an increase in population density by a factor of e is correlated to a reduction in height by 0.064 inches with a 95% confidence interval of [0.004, 0.124] (p=0.03) (Table 4). However, the relationship between height and population density for women appears to be two-level (above and below a density of e^9 = 8,100 per square mile) rather than linear (Figure 3). The heights in the low and medium density regime exceed those in at high densities by a half-inch.[12]

Similar results are found for the correlation of BMI with local population density for both men and women. We find that a factor of e increase in population density is correlated to a decrease in BMI of 0.13 for men (p=0.13) and 0.14 women (p=0.04) (Table 5). However, the plots of adjusted mean BMI with respect to density indicate a non-linear relationship for men (Figure 6) while they plausibly support an approximately linear model for women[13] (Figure 5).

Table 5 and Figures 4 and 5 about here

The sample does not permit us to directly eliminate foreign born individuals, however since it does have "Hispanic" and "Other" categories, we believe that the foreign born are largely eliminated through our exclusion criterion. However, if the fraction of foreign-born individuals in a zip code is included in the regressions, the sizes of all population density correlations are reduced to insignificance. We believe that such an adjustment is inappropriate, for three reasons. First, as our model uses individual factors such as personal income and personal environment expressed through population density to predict height, including the number of foreign-born individuals in a person's zip code is conceptually problematic. Second, the fraction foreign-born in a zip code is very highly correlated with population density (r=0.63), so the regression becomes unstable when both variables are included. Third, and most importantly, the individuals likely to be foreign born are eliminated through the "Hispanic" and "Other" categories at rates we would expect if such categories were eliminating most of the foreign born (Figure 6). We find that the number of individuals eliminated by this method as a function of fraction foreign-born to both be uniformly greater than and to scale with the fraction of individuals who are foreign born in those districts. However, while this indicates that we are likely eliminating most of the foreign-born from the sample—consistent with the fact that most of the foreign-born population in the U.S. is non-white—we cannot be sure that the entirety of that sample is being eliminated, and may be contributing to our observed relationship between height, BMI, and population density.

Figure 8 about here

Local Environmental Predictors: Economic Conditions

We examined marginal positive correlations between male height and local economic conditions as measured by poverty rate, unemployment rate and median income. Insofar as these results were not significant after adjustment for population density, we find no evidence that local economic conditions considered separately from personal income have any predictive power regarding height or BMI.

Conclusion

The Sizing Survey is not a random sample of the US population and the patterns found in these data should be considered preliminary. First among these is a strong negative correlation between white male height and population density of residence. For white women, this relationship is weaker and may reflect a distinction between those living at densities greater and less than about 8000 persons per square mile. It is possible that these results are influenced by our limited ability to screen out foreign-born individuals, who are more heavily concentrated in urban areas. We find some evidence that population density is more strongly correlated with BMI within a community than across communities, with larger individuals living in lower densities within their area regardless of that area's absolute density.

Insofar as urban communities have superior access to medical care, rural populations are often shorter than urban populations (Komlos and Kriwy 2003). Though we find negative correlations between height and population density, our result does not necessarily disprove this hypothesis, as rural densities are under-sampled in our data. The negative correlations we observe are robust between suburban or small town densities and those found in cities rather than between rural and urban densities. Nonetheless, our findings might indicate the influence of urban disamenities on height. The fact that there is a simultaneous negative correlation with BMI complicates the process of linking these results to claims about biological welfare.

Because terminal height can only be influenced by conditions during childhood and adolescence, we expect that geographic movement of individuals between adolescence and adulthood would diminish differences caused by disparate childhood conditions (if the movement is to locations that are substantially different from the location of childhood). However, the same movement of individuals could lead to the creation of geographic height gradients if a mechanism by which individuals sort into certain types of areas exists. While the U.S. census does not find any difference between absolute movement rates for men and women that might explain the strong observed population density correlation for men,[14] it may be that the choice of movement destination rather than the number of movements is at issue. There is greater socioeconomic mobility among women in the United States; daughter's incomes are less strongly correlated with their fathers' incomes than sons' incomes are (Peters, 1992). Consequently, two hypotheses emerge for the disparity between men and women. First, it may be that men carry forward more of their childhood differences due to less mobility-induced mixing, which presumes that living at such densities is, in fact, beneficial. Second, it may be that men are choosing the destination of their movement based on factors that are correlated with their own height, a sorting hypothesis.

The hypothesis that higher densities lead to lower height would indicate that American suburbs and moderately sized towns, the low end of our sampled density range, are providing the best mix of benefits for biological welfare: easy access to medical care and few of the negative environmental conditions found in urban areas. To confirm such a conclusion, it would be necessary to show a link between these densities and health, perhaps by using a sample of children. Supporting the sorting hypothesis is the fact that height has been shown to predict personal economic success (Persico, Postlewaite, and Silverman 2004) and more strongly for men than for women (Heineck, 2004). If those who are successful are preferentially moving to suburbs with low density, this might create the height gradient we observe, though adjusting for individual income would compensate for such a difference if the income data in the sample were perfectly accurate. Given the small number of income categories and the fact that income is self-reported, it may be that our income adjustment is incomplete. Finally, a psychological explanation might be applicable as well, that among those with equal income, individuals who are physically larger make choices about financial allocation regarding the size of their residence that push them towards lower density areas.

In sum, the US Size Survey is not quite representative of the US population. It under sampled people living at low population densities (under 150 people per square mile) and over sampled those living in moderate densities (between 150 and 3000 people per square mile). This bias was linked to its strategy to collect samples at shopping malls, but as it turns out this had the consequence of obtaining an anthropometrically biased sample, especially among women. While young men (18-25) in the sample are 0.8 inches taller than the national average, young women in the sample are 11 pounds lighter and 0.6 inches taller than the national average. Evidently, the individuals doing their shopping in malls more active and hence less likely to be obese than the general population. Nonetheless, we have found that height decreases substantially among US men with the population density of their residence. The difference in men's height between low- and high-density residences is 1.75 inches (4.5 cm), after controlling for own income and education. The inference is that men either select themselves in such a way that taller men choose to live in low-density environments or that there are spillover effects that have a negative impact on height of men in high density cities to the extent that current residence type correlates positively with residence type during childhood. This effect is not so marked among women: about 0.5 inches (1.25 cm). BMI also varies somewhat by residence type, with people living in low densities weighing more than those who live in high density environment, a disparity that seems to be stronger within individual communities than it is across the country as a whole. While we are unable to provide a satisfactory explanation for these patterns, the results reported here nonetheless do point to further research taking advantage of the relationship between living environment and lifestyle as a means to explain why Americans have fallen behind Western Europeans in height since the 1960s but surged well ahead in weight since the 1980s.

Table 1: Tables of height as a function of age for men and women in the Size USA and in the NHANES 1999-2002 survey, by race. While there is agreement on BMI and weight (W) for white men, the Size USA data appears to overestimate male height. For white women, the Size USA survey data overestimates height, underestimates weight and consequently strongly underestimates BMI.

White:

HEIGHT (in)	Men						Women					
Age Group	NHANES			Size USA			NHANES			Size USA		
	H	BMI	W	H	BMI	W	H	BMI	W	H	BMI	W
18-25	69.5	25.9	178.1	70.3	25.2	176.7	64.1	26.2	152.8	64.7	23.8	141.5
26-35	69.6	27.2	187.4	70.4	27.2	192.0	64.2	27.9	163.7	64.8	25.9	154.2
36-45	69.7	28.0	193.7	70.1	28.2	196.6	64.3	28.3	166.5	64.7	26.8	159.3
46-55	69.5	28.7	196.7	69.6	28.8	197.9	64.1	28.8	168.0	64.2	27.6	162.0
56-65	68.8	28.7	192.7	69.4	28.7	196.4	63.6	29.8	170.7	63.9	27.6	159.9

Black:

HEIGHT (in)	Men						Women					
Age Group	NHANES			Size USA			NHANES			Size USA		
	H	BMI	W	H	BMI	W	H	BMI	W	H	BMI	W
18-25	69.9	25.3	175.5	69.7	26.3	181.5	64.1	28.8	168.5	64.5	26.7	157.8
26-35	69.9	27.7	192.9	69.2	29.4	198.9	64.7	30.8	183.8	64.6	29.7	176.1
36-45	70.1	28.1	196.0	69.5	28.3	193.8	64.4	31.6	186.9	64.7	30.9	183.9
46-55	69.5	27.3	187.5	69.7	27.5	189.9	64.5	31.8	187.4	64.7	30.5	181.0
56-65	69.2	28.5	194.4	70.4	28.3	198.1	63.9	31.9	185.2	64.0	31.0	179.7

Hispanic:

HEIGHT (in)	Men						Women					
Age Group	NHANES			Size USA			NHANES			Size USA		
	H	BMI	W	H	BMI	W	H	BMI	W	H	BMI	W
18-25	68.0	25.8	169.7	67.6	26.1	170.1	62.6	27.0	150.1	62.8	25.1	140.1
26-35	66.9	27.4	174.7	66.8	26.7	181.9	62.7	28.4	158.2	62.5	27.6	152.8
36-45	67.7	28.0	182.1	67.0	29.2	186.4	62.4	29.2	161.3	62.2	29.0	159.0
46-55	66.8	28.5	181.0	66.7	28.4	179.1	62.0	30.1	164.3	62.1	29.7	162.9
56-65	66.3	27.7	175.6	65.3	30.0	181.3	61.5	30.7	164.8	61.3	29.1	155.2

Table 2: Table of height coefficients for age, income, and education factors in the sample of white men and women under age 65. All factors are reported with respect to the baseline individual: an 18-25 year old, college-educated individual with income over $100,000.

HEIGHT (inches)	Men			Women		
Factor	n	Coef.	t	n	Coef.	t
Intercept	1524	**71.67**	243.7	2903	**65.54**	223.3
Age						
18-25 (Birth Cohort: 1976-1983)	469	Ref.	-	670	Ref.	-
26-35 (1967-1976)	280	-0.13	-0.5	611	**-0.31**	-2.0
36-45 (1957-1966)	335	**-0.50**	-2.1	636	**-0.48**	-3.0
46-55 (1947-1956)	270	**-1.09**	-4.3	620	**-0.95**	-6.0
56-65 (1937-1946)	173	**-1.25**	-4.2	366	**-1.15**	-6.4
Income						
< 25K	458	**-1.01**	-3.7	614	**-0.76**	-4.3
25K – 50K	321	**-0.95**	-3.4	764	**-0.41**	-2.6
50K – 75K	289	**-0.63**	-2.3	645	-0.16	-1.0
75K – 100K	201	**-0.57**	-1.9	431	-0.06	-0.3
100K+	254	Ref.	-	449	Ref.	-
Education						
Less than High School	53	**-2.07**	-4.4	56	**-1.83**	-5.0
High School	298	**-0.83**	-3.2	442	**-0.58**	-3.8
Some College	485	-0.40	-1.7	986	**-0.24**	-2.0
College	412	Ref.	-	968	Ref.	-
Post-Graduate	275	-0.33	-1.3	451	0.14	0.9
Adjusted R^2		0.038			0.040	

Note: Bold indicates that the coefficient is significant at the 5 percent level.

Table 3: Table of BMI coefficients for age, income, and education factors in the sample of white men and women under age 65. All factors are reported with respect to the baseline individual: an 18-25 year old, college-educated individual with income over $100,000.

BMI	Men			Women		
Factor	n	Coef.	t	n	Coef.	t
Intercept	1524	**24.7**	52.9	2903	**21.8**	52.3
Age						
18-25 (Birth Cohort: 1976-1983)	469	Ref.	-	670	Ref.	-
26-35 (1967-1976)	280	**2.1**	5.3	611	**2.7**	7.6
36-45 (1957-1966)	335	**3.2**	8.4	636	**3.7**	10.6
46-55 (1947-1956)	270	**3.9**	9.6	620	**4.6**	12.9
56-65 (1937-1946)	173	**3.8**	8.1	366	**4.4**	10.8
Income						
< 25K	458	-0.0	0.0	614	**1.3**	3.3
25K – 50K	321	0.7	1.7	764	**1.4**	4.0
50K – 75K	289	0.5	1.2	645	**1.4**	3.8
75K – 100K	201	-0.2	-0.5	431	-0.1	-0.3
100K+	254	Ref.	-	449	Ref.	-
Education						
Less than High School	53	0.5	0.7	56	**3.0**	3.7
High School	298	0.2	0.4	442	0.6	1.8
Some College	485	0.5	1.4	986	**1.3**	4.7
College	412	Ref.	-	968	Ref.	-
Post-Graduate	275	-0.3	-0.8	451	-0.2	-0.6
Adjusted R^2		0.082			0.081	

Note: Bold indicates that the coefficient is significant at the 5 percent level.

Table 4: Regression results for height as a function of log(population density). The intercept is given at the sample mean log(population density) of 7.31 (1500 per square mile). Note the change in R^2 for male height with respect to the initial factor analysis in Table 2. Including the population density term in the regression explains 31% more of the variation in men's heights versus only 3% more for women. For women, population density has little explanatory power above that provided by the individual education, income and age factors, however for men it appears to be a powerful predictor of height.

HEIGHT (inches)	Men			Women		
Variable	n	Coef.	t	n	Coef.	t
Intercept	1524	**71.53**	243.7	2903	**65.55**	353.7
Log(Population Density)	1524	**-0.25**	-4.7	2903	**-0.06**	-2.1
Age						
18-25 (Birth Cohort: 1976-1983)	469	Ref.	-	670	Ref.	-
26-35 (1967-1976)	280	0.05	0.2	611	**-0.31**	-2.0
36-45 (1957-1966)	335	-0.34	-1.4	636	**-0.48**	-3.0
46-55 (1947-1956)	270	**-0.92**	-3.6	620	**-0.95**	-6.0
56-65 (1937-1946)	173	**-1.13**	-3.8	366	**-1.15**	-6.4
Income						
< 25K	458	**-0.92**	-3.4	614	**-0.76**	-4.3
25K – 50K	321	**-0.91**	-3.3	764	**-0.41**	-2.6
50K – 75K	289	**-0.65**	-2.4	645	-0.17	-1.0
75K – 100K	201	**-0.62**	-2.1	431	-0.06	-0.3
100K+	254	Ref.	-	449	Ref.	-
Education						
Less than High School	53	**-1.83**	-3.9	56	**-1.83**	-5.0
High School	298	**-0.77**	-3.0	442	**-0.58**	-3.8
Some College	485	**-0.43**	-1.9	986	**-0.25**	-2.0
College	412	Ref.	-	968	Ref.	-
Post-Graduate	275	-0.40	-1.6	451	0.14	0.9
Adjusted R^2		0.051			0.041	

Note: Bold indicates that the coefficient is significant at the 5 percent level.

Table 5: Regression results for BMI as a function of log(population density). The intercept is given at the sample mean log(population density) of 7.31. Note that the changes in R^2 versus Table 3 are very small, even though the coefficients are near-significant and significant for men and women, respectively. This indicates that covariance between the population density term and the other variables is the cause of the significant terms and that population density provides little additional explanatory value over the income, education and age factors for BMI.

BMI	Men			Women		
Factor	n	Coef.	t	n	Coef.	t
Intercept	**1524**	**24.61**	52.5	**2903**	**21.81**	52.4
Log(Population Density)	1524	-0.14	-1.7	2903	**-0.14**	-2.1
Age						
18-25 (Birth Cohort: 1976-1983)	469	Ref.	-	670	Ref.	-
26-35 (1967-1976)	280	**2.25**	5.5	611	**2.72**	7.7
36-45 (1957-1966)	335	**3.29**	8.6	636	**3.71**	10.6
46-55 (1947-1956)	270	**3.98**	9.7	620	**4.56**	12.9
56-65 (1937-1946)	173	**3.9**	8.3	366	**4.37**	10.8
Income						
< 25K	458	0.04	0.1	614	**1.38**	3.4
25K – 50K	321	0.75	1.7	764	**1.43**	4.0
50K – 75K	289	0.50	1.1	645	**1.36**	3.7
75K – 100K	201	-0.25	-0.5	431	-0.13	-0.3
100K+	254	Ref.	-	449	Ref.	-
Education						
Less than High School	53	0.64	0.9	56	**3.12**	3.8
High School	298	0.19	0.5	442	0.61	1.8
Some College	485	0.46	1.3	986	**1.22**	4.5
College	412	Ref.	-	968	Ref.	-
Post-Graduate	275	-0.35	-0.9	451	-0.26	-0.8
Adjusted R^2		0.083			0.082	

Note: Bold indicates that the coefficient is significant at the 5 percent level.

Figure 1: Distribution of log(population density) in the Sizing Survey sub-sample under analysis. Superimposed on this histogram is the distribution for the entire U.S. population, according to the U.S. Census (normalized to the Sizing Survey sample size). The Sizing Survey over counts moderate densities (150 to 3000 per square mile) at the expense of low densities, which are poorly represented in the sample. We can only consider our results between log(population density) 4 and 11 as robust. The mean log(population density) for the sample is 7.31 (1500 per square mile) versus 6.77 (875 per square mile) for the U.S. population.

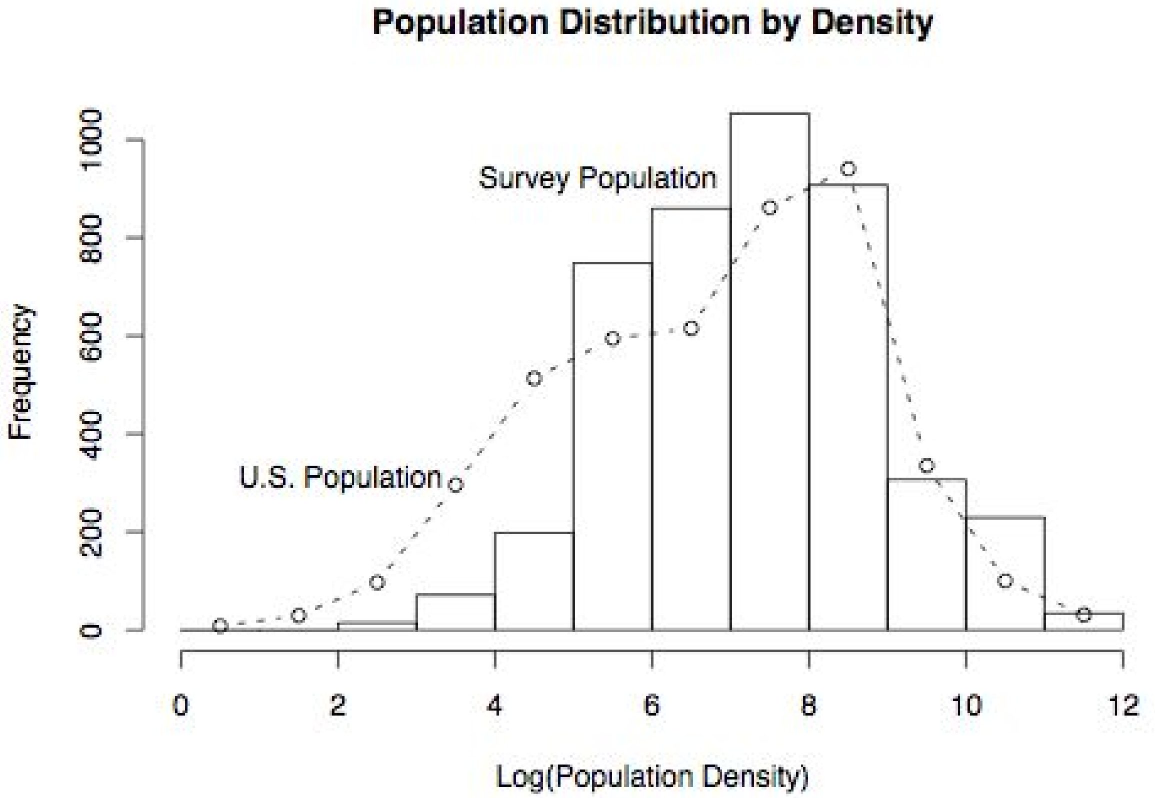


Figure 2: Male height, adjusted for age, education, and income categories, as a function of log (population density). Each point is the mean adjusted height for densities between adjacent integer values of log(population density). The regression line is plotted as a solid line over the range from e^4 to e^{11} where the data are dense. The 95% confidence interval for each point is depicted with dashed lines.

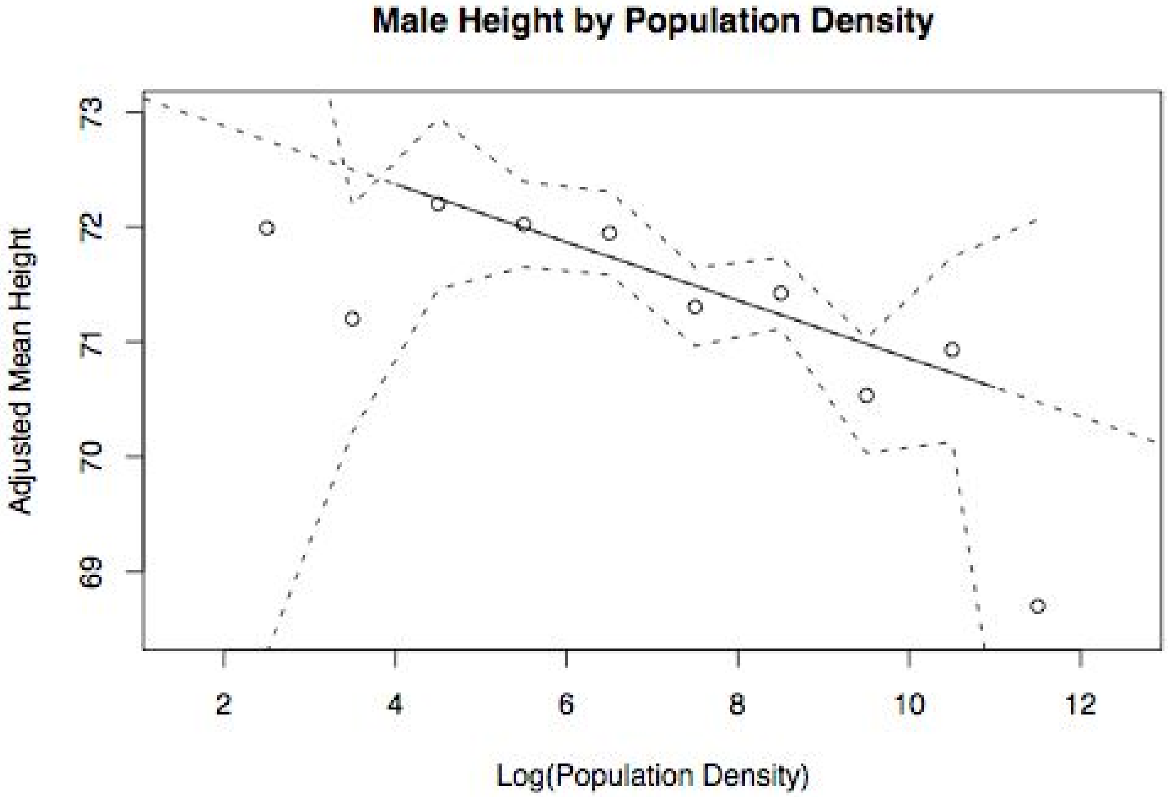


Figure 3: Female height, adjusted for age, education, and income categories, as a function of log (population density). Each point is the mean adjusted height for densities between adjacent integer values of log(population density). The 95% confidence interval for each point is depicted with dashed lines. The regression line described in Table 4 is plotted as a dashed line because there is evidence from the plot that the dominant effect is not linear, but bi-level. Plotted as two solid lines at 65.63 inches and 65.07 inches are the mean values for the women above and below a population density of e^9 (8100 per square mile).

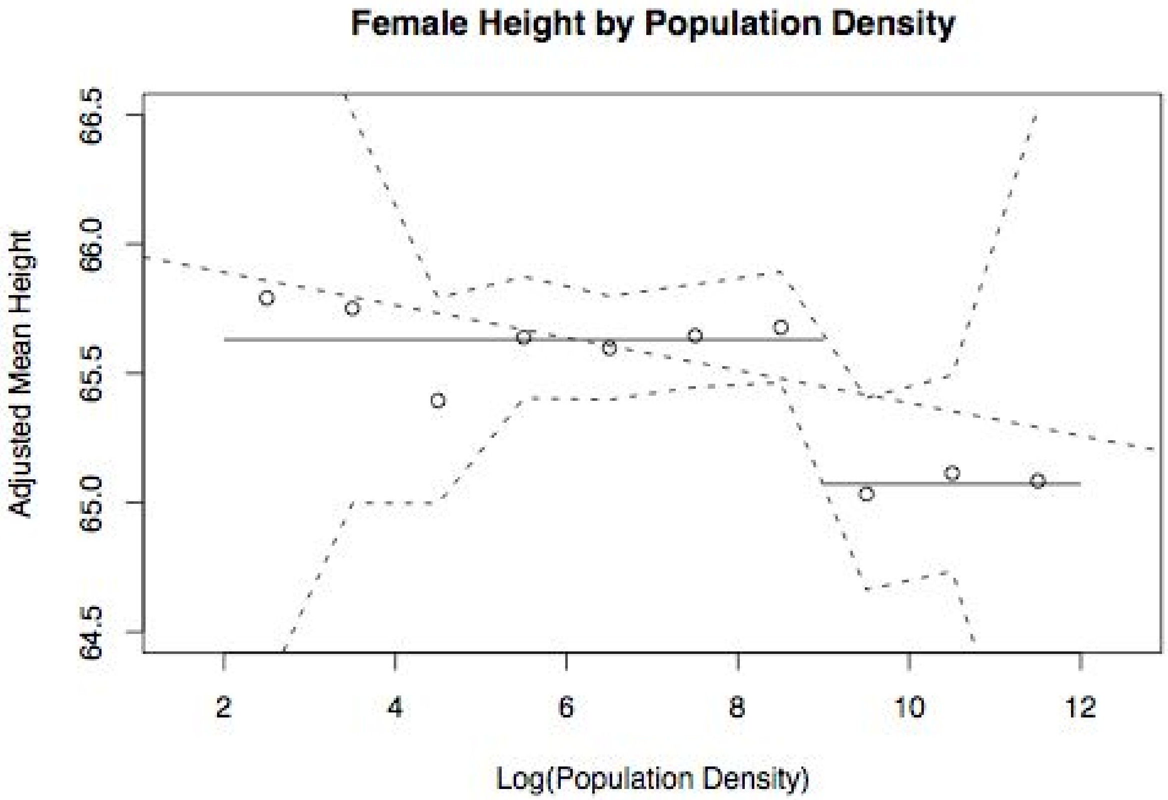


Figure 4: Male BMI, adjusted for age, education, and income categories, as a function of log (population density). Each point is the mean adjusted height for densities between adjacent integer values of log(population density). The linear model (dashed line) described in Table 5 seems not to fit the data. The 95% confidence interval for each point is depicted with dashed lines.

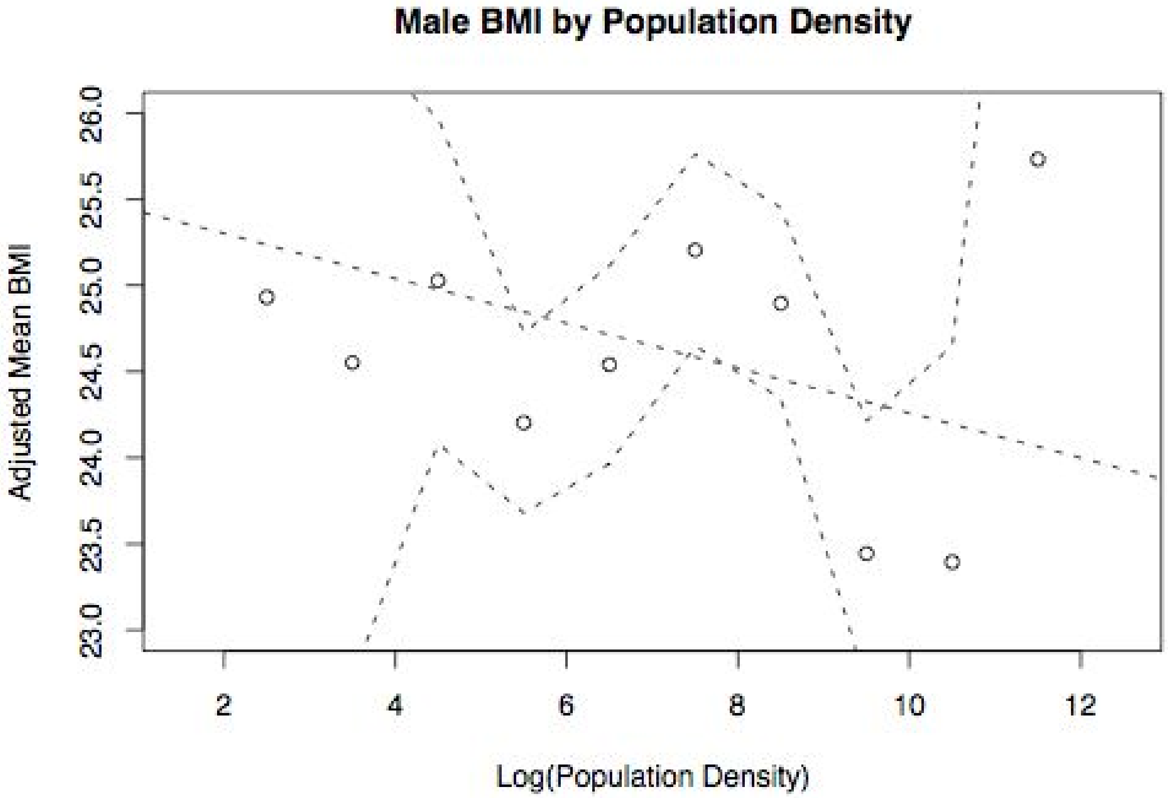


Figure 5: Female BMI, adjusted for age, education, and income categories, as a function of log (population density). Each point is the mean adjusted height for densities between adjacent integer values of log(population density). The linear model (dashed line) described in Table 5 is mostly followed by the data, however the higher density groups seem not to follow this model. The 95% confidence interval for each point is depicted with dashed lines.

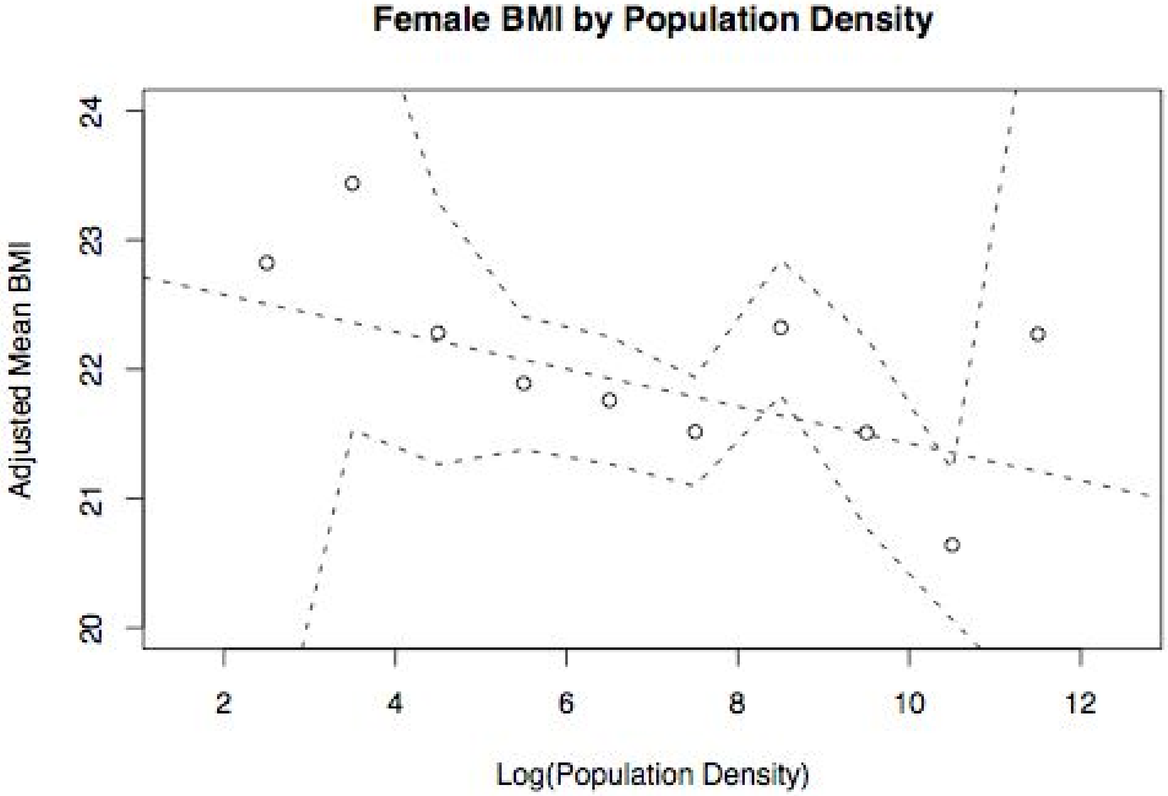
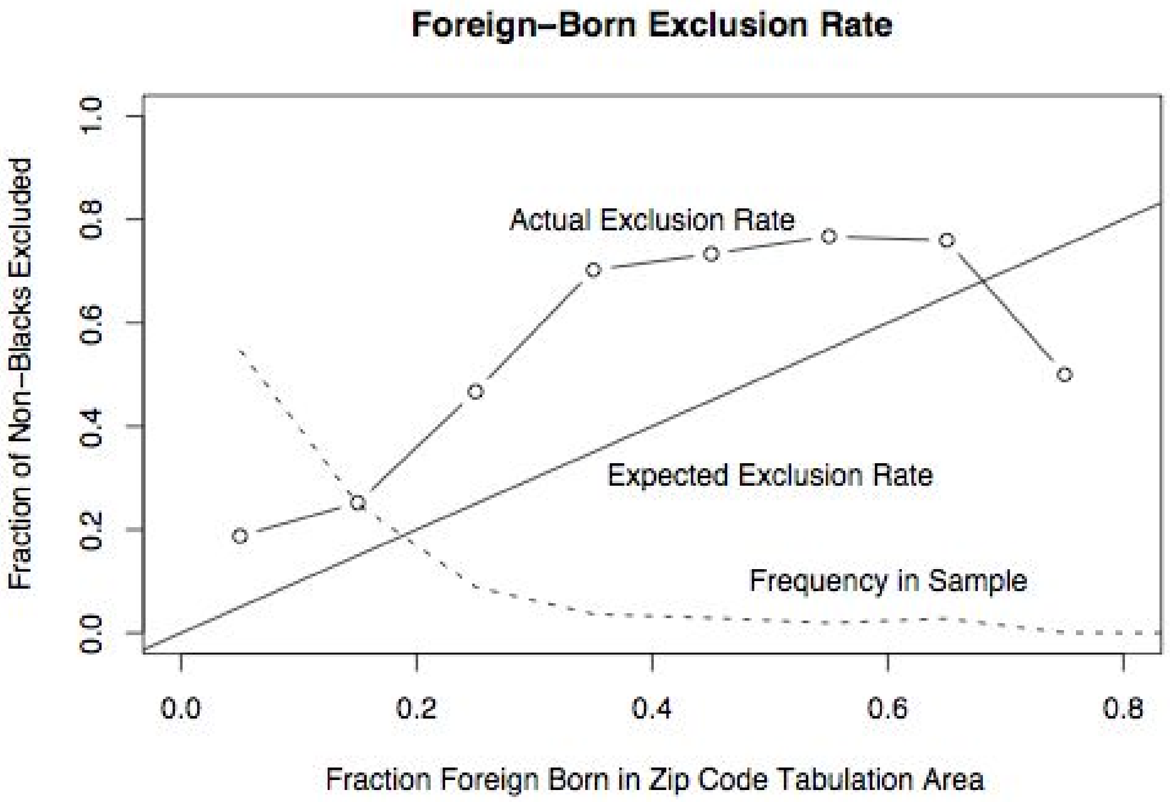


Figure 6: Rate of exclusion from the non-black sample as a function of fraction foreign born in zip code tabulation area. A straight line is plotted at the rate of rejection expected if all individuals in the "Hispanic" and "Other" categories were foreign born. The rate of rejection is higher than this baseline (the final point corresponds to just four individuals, of which two are eliminated) and scales properly as a function of fraction foreign born in zip code. This suggests that most of the foreign born individuals are successfully rejected. The dashed line indicates the distribution of individuals in the final sample as a function of fraction foreign born.



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Endnotes

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1 All body measurements with the exception of height and weight, were measured with a three-dimensional full body scanner.

2 The cluster locations were: Cary, NC (825 individuals); Columbia, MO (772); Dallas, TX (969); Miami, FL (57); New York, NY (250); Chattanooga, TN (268); Los Angeles, CA (62); San Francisco, CA (203); Portland, OR (156); Winston Salem, NC (416); Buford, GA (106); Lawrence, MA (658); Glendale, CA (334).

3 Sedentary populations may be less likely to travel to shopping centers.

4 Zip codes are postal codes that are generally well correlated to geographic areas, especially in highly populated areas. However, since they are assigned for addresses, they do not actually have land area associated with them directly. Consequently, the Census Bureau created geographic areas, ZCTAs, which correspond to these addresses. Because there is some freedom in demarcating the borders of such regions in unpopulated areas, the ZCTA codes include additional codes so that water and unpopulated areas are not included in the ZCTAs that correspond to Zip Codes. For further discussion of how ZCTAs were developed and how they correspond to census blocks and other regions, http://www.census.gov/geo/ZCTA/zcta.html

5 We considered eliminating 18-25 year-old men from the sample due to the possibility that they may not be fully grown, however they were included as we found their presence did not change any results significantly.

6 For these results, we have not adjusted for site since this regression is for the purpose of illustrating categorical trends in the data (only two of these site factors are significant: women from Glendale, CA are shorter than average and women from Dallas, TX have greater BMI.)

7 Some of this increase might be due to old-age shrinking. The more recent birth cohort 1967-1976 shows a mere 0.3 inch increase for women and none for men. In contrast, heights for European men and women have continued to increase since the 1950s and have now overtaken and exceeded American heights.

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8 A few examples are useful in assessing this distribution. The densest zip code in the sample, "10009" on the Lower East Side of Manhattan, had a density of just over 100,000 per square mile. "02138" in Cambridge, MA, the urban residential and commercial area including Harvard University, has a density of 12,500 per square mile. A very wealthy suburban area outside of Los Angeles, "90210", has a density of 2300 per square mile. 66049, in Lawrence, KS, has a density of 410 per square mile. These four locations correspond to Log(Population Densities) of 11.5, 9.4, 7.7, and 6.0.

9 The mean log(population density) for the sample is 7.31 (1500 per square mile) versus 6.77 (875 per square mile) for the U.S. population.

10 The aforementioned problem of whether to adjust for cluster is especially difficult in the case of population density given that each cluster has a much narrower distribution of densities than the entire sample. Such adjustment tests something different from the range of heights over the full range of densities: it tests if there are differences in heights between different density areas within a single community. Consequently, we present the results without adjustment for cluster, but discuss the consequences of such adjustment to test the robustness of significant results.

11 With adjustment for cluster site the magnitude of the correlation is reduced from –0.25 to –0.17 (+/- 0.15) with p=0.02 and remains linear over the full range of data after adjustment, indicating that within individual clusters there is still a strong height gradient.

12 Adjusting for cluster site eliminates all dependence of height on population density for women (p=0.95).

13 The magnitude of the correlation increases (and reaches the 95% confidence threshold for men) after adjustment for cluster, -0.24 +/- 0.23 (p=0.04) for men and -0.26 +/- 0.19 (p=0.008) for women. The magnitude of this increase is not itself significant, but such an increase would indicate that weights are correlated with population density more strongly within each cluster than they are across all clusters. This perhaps indicates that sorting, rather than inherent effects of particular densities, is the cause for such differences: people who have higher BMIs are choosing to live in lower density areas within the

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region near their employment. Since our adjustment for education and income may not be perfect, we may be observing that within a region, the higher density areas are on average wealthier. Since weight is negatively correlated with income for women, an imperfect adjustment would create just this type of in-cluster gradient.

[14] U.S. Census Bureau, Current Population Survey, 2003 Annual Social and Economic Supplement. Tabulated by at http://www.infoplease.com/ipa/A0922200.html