THE EARLY ACHIEVEMENT OF MODERN STATURE IN AMERICA

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There are many reasons why the level of nutrition has been a subject of great concern to scholars of early America. One of the obvious motives for the attention is that nutrition is related to more conventional economic variables of which we have limited knowledge during that period. Those frustrated by the lack of data to compute income estimates, might be able to utilize indicators of nutrition as a crude substitute. Although the two variables may not move closely together, even in a developing economy where food consumption is a major component of the standard of living, evidence of significant changes in nutrition might suggest that there was at least the potential for change in income. Hence, information about nutritional levels can have implications for issues of standard of living, economic growth, and distribution of income.

While food is normally considered a consumption good, its contribution to production has also begun to be studied. Only recently, two economic historians attributed great significance to the state of nutrition during the eighteenth century and thrust a role on center stage upon it.[1] They proposed that the capacity of men to work and produce increased substantially during the late seventeenth and early eighteenth centuries, largely because of improvements in nutrition, and that the latter advance may have been a necessary condition for the Industrial Revolution. This view that nutrition is an important form of human capital, or that it might be treated as an input in production processes, has received more attention as economists have become increasingly aware of the problems of developing nations. Several studies, conducted in both the field and the laboratory, have established that the level of nutrition can have significant effects on worker productivity.[2]

Finally, one of the principal issues in the attempt to explain the secular decline in mortality rates over the last several centuries, both in Europe and in North America, is the role played by nutrition. It was an interest in studying

these changes in mortality that originally inspired our investigation. While many scholars have argued that improvement in nutrition was the major factor accounting for the decline in death rates, this interpretation has not passed without challenge.[3] Many alternative contributors to this development have been suggested, and they include medical advances, an increasing knowledge of the operation of the physical world (personal health measures), improvements in housing, decreasing virulence of disease, and the implementation of public health measures.

Despite the importance of the issues concerning the amount and nutritional adequacy of the food supply, efforts to study this subject were initially hampered by a lack of evidence. It may be possible to resolve this problem by utilizing information on height by age. Data on both height and weight, by age, are particularly desirable for identifying a population's "average nutritional status." While such joint distributions are sometimes available, only data on height have thus far been located in such quantities that they can be used to construct time series extending back into the eighteenth century. Even without observations of weight, height-by-age data can be quite accurate indicators of the "average nutritional status" of populations, as well as of differences in this condition over time and place.[4]

Many researchers have studied the effects of nutritional deficiencies and illness on the height-by-age profile through observational studies of human populations and laboratory experiments.[5] Three statistics are particularly useful: the age at which the adolescent growth spurt peaks, the age at which full height is attained, and the change in terminal heights over time. Short periods of malnutrition or prolonged spells of moderate malnutrition, during childhood, merely delay the onset of the adolescent growth spurt. Severe, prolonged malnutrition may completely erode the typical growth-spurt pattern

and cause permanent stunting. If malnutrition is sustained over an extended period, but moderate, growth will continue beyond the age at which it normally ceases in well-fed adolescents. Hence, the age at which growth terminates is an important indicator of nutritional status, especially for older adolescents. There is a clear pattern of "catching-up" after periods of malnutrition, but the longer the periods and the more severe the malnutrition, the more likely the terminal height will fall below what it would have been under conditions of good nutrition. Malnutrition is not the only environmental influence on height-by-age profiles. Major illnesses can be detected by the existence of "slowdowns" in velocity profiles, followed by acceleration in growth after recovery.

Recent studies have suggested that the effects of malnutrition are manifested not only in the immediate generation, but in subsequent ones as well. This may be the mechanism which produces the observed secular increase in final heights of various populations for which long-term series are available.[6] The final heights of different populations thus appear to be a significant index of the cumulative effect of the nutritional status of these populations over several generations.[7] This is not to imply that radical changes in diet cannot result in a large change in the average terminal heights between children and parents (i.e. a temporal span of a single generation). The experience of the Japanese during the post-war period is a well known case of rapid growth in the heights of a population within a generation. A study of Italian-Swiss immigrants in twentieth century California reported that the first generation achieved a mean terminal height that was approximately four centimeters taller than that of their fellow villagers and family members who remained in Switzerland.[8]

DATA

Military records, both in the nature of the information they contain, as well as in the span over time and place for which they are available, are a rich source of height-by-age data. In this paper, we shall be reporting on our analysis of this type of historical document, a kind which has not generally been examined systematically for any purpose. The records we have utilized, referred to as muster rolls or descriptive lists, are predominantly from the years of the French and Indian War (1756-1763) and the American Revolution (1775-1783), and pertain to the soldiers of the American Colonies. Such lists were compiled for most colonial military forces, typically by individual companies of regiments, and provided the basis for distributing supplies and payments, as well as aiding in the identification of deserters. Since there was no standard format, the information appearing in the muster rolls varies widely. Lists have been retrieved that included for each soldier some, but never all, of the following information: place of birth, age, place of residence, occupation, height, hair color, eye color, complexion, place and data of enlistment, military rank, by whom enlisted, language spoken, term of service, pay scale, and other assorted remarks relevant to military service. The muster rolls, of course, provide more abundant evidence on final heights and on the age at which growth terminates than on the peak of the growth spurt. As one would expect, very few individuals under the age of 16 enlisted in the military, making it difficult to utilize these data for studying adolescent growth spurts. Accordingly, the analysis of the height-by-age data, in this paper, will focus on the terminal heights achieved.

We have also collected a sample of U.S. Army muster rolls, for those recruits who enlisted during the period 1815-1820. These lists are of a similar nature to those of the earlier era, except that they are much more uniform with regard to the information included.

Unfortunately, the format employed by the U.S. Army recorded place of enlistment instead of residence, an impediment made more serious by the practice of having only one enlistment station per congressional district.

The information examined in this paper is drawn almost entirely from those muster rolls that list at a minimum, for each recruit, height, age, and place of birth. The problem is unlikely to be significant for the U.S. Army data, as they are composed of a random sample of the total population of enlisted men; but for the earlier period, the subset of observations which included these variables is only a fraction of the total surviving sample of muster rolls, and may not be wholly representative of the population. If the data reflected only a sub-sample of recruits, the information they provided might be quite limited in scope or deceptive. With respect to the French and Indian War period, the observations were retrieved from materials of New York, Pennsylvania, and Virginia, with an especially great reliance on the former, where the bulk of the American troops involved in that conflict were raised. The militia records of the only other colony which appears to have contributed substantially to the war effort, Massachusetts, do not include height-by-age data.[9] Although it seems likely that the sample includes a relatively large percentage of the French and Indian War troops, it is not clear what proportion of the population of Revolutionary War soldiers are contained. There is no consensus on the number of men that served in the militia or the Continental Army; estimates range from 100,000 to 250,000.[10]

There is no question that one would prefer our French and Indian data to have more geographic diversity. The numerical dominance of New York troops does not necessarily imply a bias in our sample, but it does indicate a more narrow base of evidence and area of study. Fortunately, the Revolutionary War sample has broad geographic coverage, and does not diverge substantially

from the crude existing estimate of the actual distribution of soldiers across states (see Table 1).[11] The ranks of the U.S. army were characterized by geographic diversity, but, relative to the general population, recruitment was weighted toward the Northeast. Another potential source of sample selection bias pertaining to the earlier periods, is that muster rolls which report height may have been prepared in atypical localities. As we are ignorant of the true compositions of the two armies, consideration of aggregate characteristics would be difficult in any case, since, even if all areas were encompassed by our sample, some might be disproportionately represented. If one possessed a sample which was actually representative of all army and militia recruits, inferences about the general population would still have to be tendered with caution. An inspection of the distributions of occupations for the soldiers from the three periods suggests that, while the occupational composition of the Revolutionary troops may not have differed substantially from that of the general population, the French and Indian, and particularly the U.S. Army (1815-1820), troops were comprised of a disproportionate number of non-agricultural, urban, and foreign-born individuals. Nevertheless, as long as the recruits in our sample are representative of their respective groups in the population, and we restrict our claims and results to well defined categories of individuals, the seriousness of the military composition problem is mitigated.

Physical Stature In Early America

In Figures 1 and 2, we present, for the Revolutionary and French and Indian Wars, frequency distributions of the heights of white native-born recruits aged 24 and 35. One can safely treat these soldiers as having achieved their final height. Since the Revolutionary sample is diverse with regard to geographic region, and one observes some relation between place of birth and stature, it is divided into three groups: New England, Middle Atlantic, and South. As our sample from the earlier war includes relatively few individuals from New England, none of which enlisted there, this regional group does not appear in Figure 2. Having a small number of observations prevents us from dividing the sample any further. The more sub-groups that can be compared, the more differences within populations will be illuminated, and the greater the likelihood that biases in the data will be detected.

We benefit here from the work of previous scholars of human stature, who have established that final heights, for a population that has experienced homogeneous environmental and nutritional conditions, are distributed normally.[12] This prior information provides us with a powerful tool. Not only can the distribution of heights be examined for normality to assess the quality of the data and the relevance of potential biases, but the knowledge that the underlying distribution is normal also allows one to devise methods for estimating the true mean for samples afflicted with particular types of biases. It is reassuring to note that several of the regional distributions generated by our samples are such that chi-square tests cannot reject the hypothesis that they were drawn from normal populations. Even for those that fail, reasonable explanations (such as heaping) are readily applicable. The chi-square test is not especially stringent however. Accordingly, our techniques for estimating the true means from distributions diverging from normality have been applied to all of the samples. Unless otherwise specified, all of the estimates reported in this paper were computed by the Quantile Bend Method.[13]

In the case of military records, the most common and serious deviation

TABLE 1

The States of Residence, or Enlistment, of the Recruits In the Samples

French and Indian War

Maryland	67 obs.	0.7%
New York	7471	82.9%
Pennsylvania	629	7.0%
Virginia	841	9.3%
Others	4	0.1%
	9012	

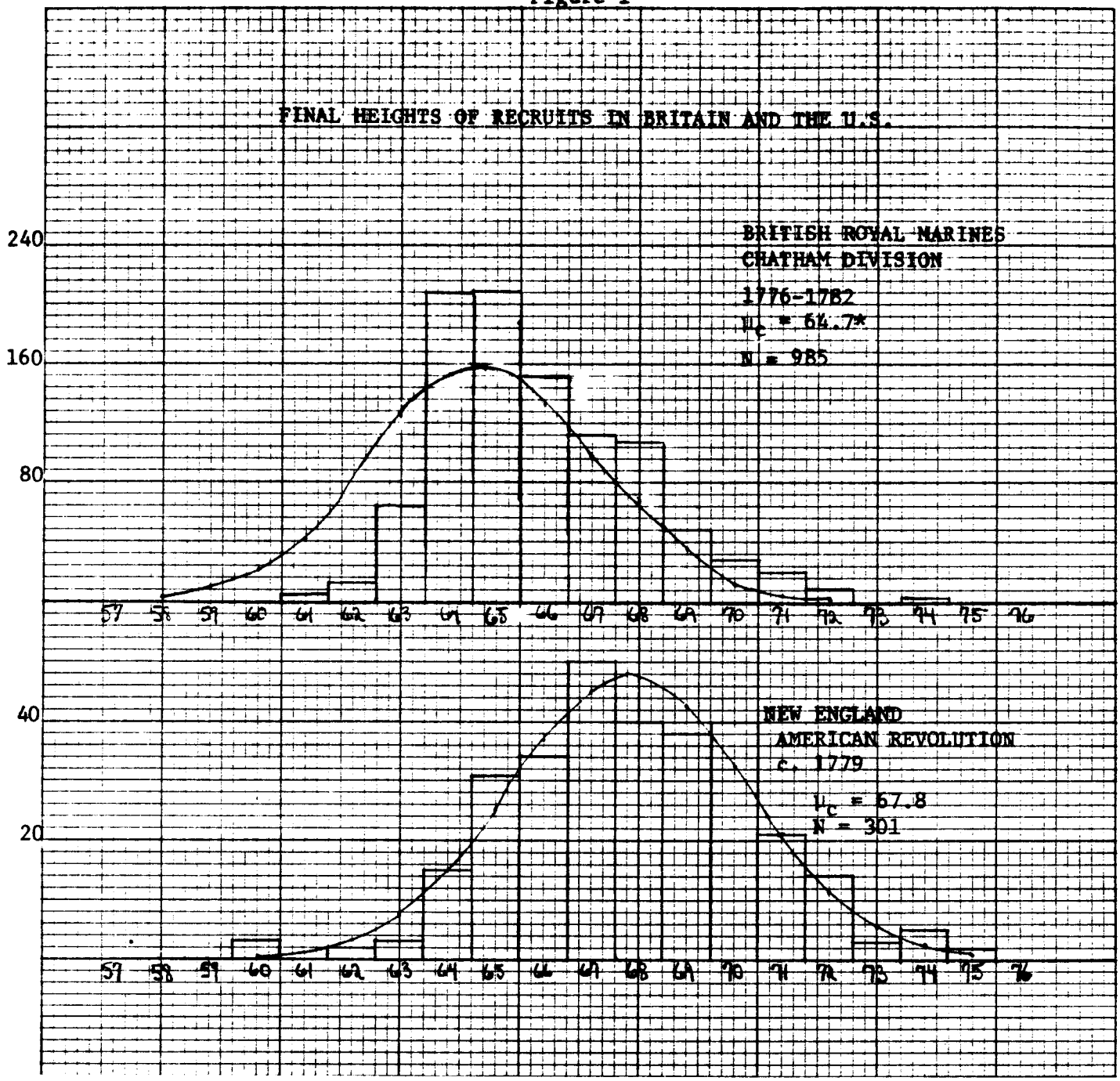
American Revolution

Connecticut (including Rhode Island)	103 obs.	1.8%
Delaware	121	2.2%
Maryland	517	9.2%
Massachusetts (Maine, New Hampshire)	1366	24.4%
New York (New Jersey)	486	8.7%
North Carolina	176	3.1%
Pennsylvania	575	10.3%
South Carolina	274	4.9%
Virginia	1990	35.5%
	5608	

U.S. Army, 1815-1820

Connecticut (including Rhode Island)	229 obs.	3.4%
Kentucky (Tennessee)	292	4.3%
Louisiana (Alabama, Florida, Mississippi)	258	3.8%
Maryland (Delaware, District of Columbia)	621	9.2%
Massachusetts (Maine, New Hampshire, Vermont)	1056	15.6%
New York (New Jersey)	1822	26.9%
Ohio (Indiana)	250	3.7%
Pennsylvania	1375	20.3%
Virginia (Georgia, North Carolina, South Carolina)	295	4.4%
Others	136	2.0%
Unknown	443	6.5%
	6777	

Figure 1



Notes to Figure 1

Note: The mean heights reported were estimated by the Quantile Bend Method. The distributions represented by bar graph are the actual distributions of heights observed in the various samples. The smoothed line indicates how a distribution of the same number of observations would be spread if it were normal and had a standard deviation of 2.5 inches. This figure approximates that characterizing white populations and falls within the 2.3 - 2.7 inches range which we observe in our samples.

*The Quantile Bend Method is normally quite robust, but in this case, it yields a wide range of plausible estimates. The Method suggests that there are two estimates of shortfall that are virtually of equal likelihood. One leads to an estimate of mean final height of 64.7 inches, the other results in one of 64.1 inches. When the Method is applied to all of the Royal Marines who served during the decades of the 1770s and 1780s, it produced final height estimates of 64.7 and 64.9 inches respectively. It thus seems likely that 64.7 inches might be a more reliable estimate of British heights during the Revolutionary War.

Figure 1 (cont.)

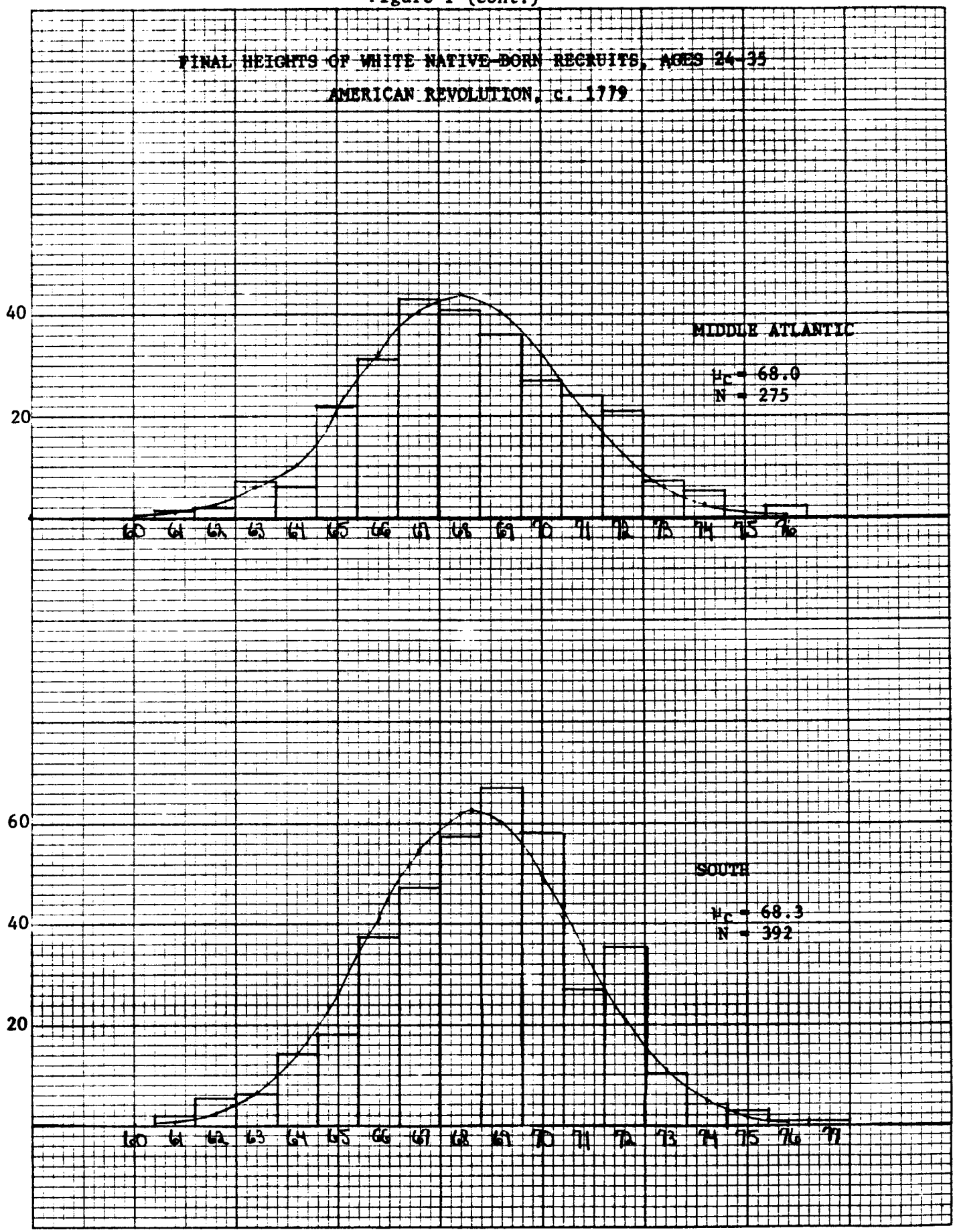
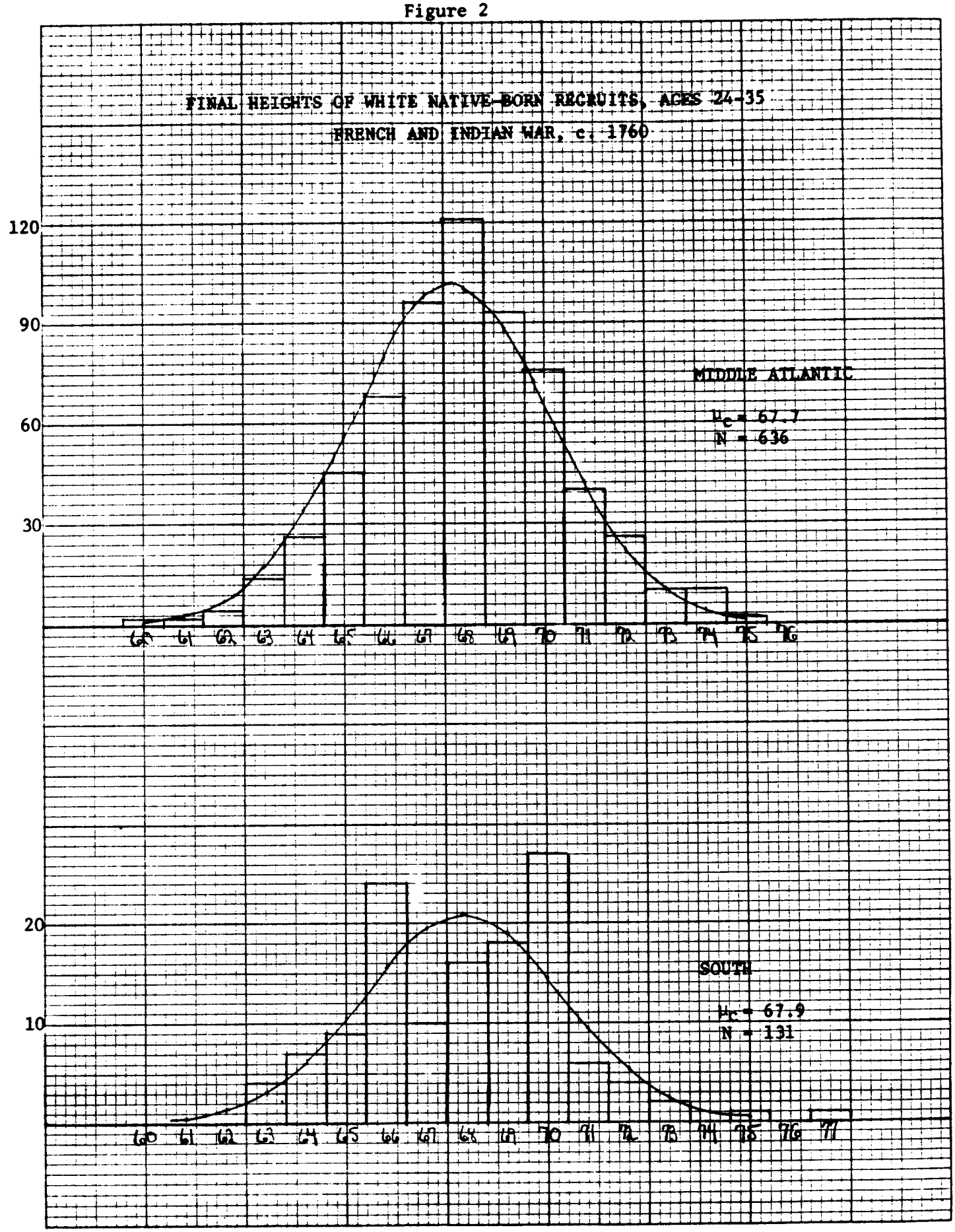


Figure 2



Note: Same as to Figure 1.

from normality is the underrepresentation of individuals with low heights. For example, as Figure 1 illustrates, British Royal Marines were not randomly recruited with respect to height. The British, like many military organizations, usually applied a minimum height requirement, the minimum varying with the demand for, and supply of, recruits. Self-selection considerations might also produce a non-random sample of the population; short individuals might prefer to avoid military service. Either phenomenon would generate left-tail truncation of the sort observed in the height distributions of British soldiers. When such truncation or shortfall occurs, the sample mean height (or the military mean final height) will be an upward biased estimate of the population's mean final height.[14] Other deviations from normality, such as "heaping", overrepresentation of taller individuals, or some combination of these problems, may also lead to biased estimates. The Quantile Bend Method that we have employed was designed to deal with these several specific types of deviation from normality. Thus, although left-tail truncation does not appear to be a major factor in the colonial American height distributions, the application of the Method yielded lower estimates of the mean final height.

The most remarkable feature about the distributions presented in Figure 1 is the evidence that native-born Americans during the Revolutionary period were quite tall by relative standards. The mean terminal heights of these groups of Americans exceed the British Royal Marine figure by amounts ranging from 3.0 to 3.5 inches. It is perhaps equally surprising that the mean terminal heights of northern Revolutionary soldiers were only 0.2 (Middle Atlantic) and 0.4 inches shorter (New England) than the average of native-born northern recruits during the Civil War.[15] The southern revolutionaries were 0.1 inches taller. The total Revolutionary sample has a mean terminal height (68.1) which is nearly equal to the World War II level.[16] Native-born Americans appear to have approached modern heights as long ago as two centuries.

As it seems unlikely that the genetic potential of the U.S. populations has changed significantly, the rather tall heights observed suggest that the colonial

population was relatively well nourished. More specifically, consumption levels of calories and protein, which are often identified as being particularly important in the influence of nutrition on height, appear to have been quite high. The inferences to be made from final heights about the average nutritional status of Americans are even more striking when one considers that members of the upper class, who would presumably be better nourished, would not be expected to appear frequently among the enlisted men. In addition, if the full effect of improvements in nutrition requires several generations to be manifested, it seems likely that the colonial level of nutrition was even higher than our sample's heights suggest. Although little is known about the diet of Americans during this period, there is some evidence that they were avid meat-eaters. One visitor to Virginia, in the 1770's remarked, "that they eat larger quantities of animal food [than at home]. . . you can be contented with one joint of meat is a reproach frequently thrown into the teeth of an Englishman."[17] If this rich source of protein was abundant, it could account for the tall stature, and, if the supply of livestock increased during the middle of the century, meat might be responsible for the growth observed. Of course, it may be that certain trace elements are critical for growth, in which case one would need to investigate the possibility of subtle changes in the diet that might have affected the intake of one or more of these critical substances. If such an event transpired it would be extremely difficult to identify given the paucity of direct evidence on food consumption.[18]

The differences between the mean final heights of the Revolutionary sub-samples may also be informative. That the southerners, on average, were 0.5 and 0.3 inches taller than the recruits born in New England and the

Middle Atlantic respectively, may reflect disparities in average nutritional status.[19] Their stature was also greater in the sample from the French and Indian War. Between the wars, heights advanced in both regions at modest paces, 0.5 inches per generation in the Middle Atlantic and 0.6 inches per generation in the South.

One might be troubled by the significant difference in mean final heights between Southerners and northerners in the Revolutionary sample. Since a higher class of individuals is supposed to have served in the New England military and this region's population had probably resided for the longest period in America, one might have expected the heights of these recruits to be greater. A possible explanation is that southerners were measured with their shoes on.[20] Some contemporaries noticed, however, that southerners seemed to be taller: "The natives for the most part, rise above the middling stature: and they attain their full height sooner, than the people usually do in colder climates!"[21] There are several other hypotheses which could account for this divergence. The apparent difference in nutrition suggested by the height-by-age data might be related to regional differences in income. This explanation would be consistent with the finding derived from probate records that the average wealth holdings were substantially higher, for nearly all classes of society, in the South relative to the Middle Atlantic and New England.[22] Another set of possible explanations concerns the agricultural differences between the two regions. Perhaps the farther south an individual lived, the more nutritious the crops, the larger the supply of livestock, the better the access to food, or the greater the quality of the food supply during the winter months. Other hypotheses might involve differences in occupational distributions, tastes in food, or in genetic potential. It should be further noted that a similar pattern appears in Civil

War data. For example, the mean height of the New England-born soldiers of the Civil War, at age 26, was 68.16 inches, while for Kentucky and Tennessee (the closest states to the southern seaboard) the mean height was 69.05 inches.[23] There is some evidence that even today the average height of southerners continues to slightly exceed that of the northern population.[24] The regional difference in heights may seem puzzling, but it should not discredit the height-by-age analysis. It is the contention of this paper that the level of nutrition did vary within the population, and that height-by-age analysis can detect some of the systematic patterns of that variation.

From the discussion of regional differences in heights, it is clear that a multivariate analysis is desirable in order to determine whether the discrepancy can be attributed to other factors not held constant. Accordingly, a regression with height as the dependent variable was run over the sub-sample of Revolutionary soldiers, ages 24 to 35. The independent variables include age and a series of dummies representing occupational classes, places of birth and residence, and race, while the intercept reflects the height of a rural New England-born white farmer who lived in a rural area. The results are reported in Table 2. It is evident that, even after allowing for other characteristics, the regional difference in height among native-born Americans persists. The results suggest that being born in Virginia added 0.6 inches to an individual's height and North or South Carolina contributed 0.8 inches. The coefficients on the other domestic nativity dummies imply that New Yorkers were also substantially taller than New Englanders. The stature of those born in other states is not significantly different from that for New England.

The regression also provides support for the view that Americans were better nourished than Europeans, as the coefficients on the foreign-born dummies are generally large, negative, and statistically significant. One must remember, however, that the immigrants who appear in the military data

TABLE 2

REGRESSION WITH HEIGHT AS DEPENDENT VARIABLE

RECRUITS FROM REVOLUTIONARY WAR

AGES 24-35

$R^2 = 0.1140$ N = 1785

Variable	Coefficient	t-statistic
Intercept	68.249	123.26
Years of Age	-0.020	-1.09
Native-born Artisan	-0.072	-0.74
Native-born Laborer	-0.028	-0.09
Foreign-born Artisan	-0.345	-1.15
Foreign-born Laborer	0.323	0.83
Foreign-born Farmer or Professional	-0.777	-2.15
Seaman	-0.108	-0.27
Unknown Occupation	0.041	0.20
Born in Native Urban Area	-0.377	-0.88
Born in Foreign Urban Area	-0.952	-3.12
Urban Resident	-0.901	-1.71
Foreign-born Urban Resident	0.722	1.13
Non-white	-0.606	-1.46
Southern Non-white	-1.051	-1.62
Born In New York or New Jersey	0.862	3.04
Born in Pennsylvania or Delaware	0.063	0.21
Born in Maryland	0.276	0.79
Born in Virginia	0.598	2.88
Born in North or South Carolina	0.781	2.17
Others Born in America or Canada	0.063	0.19
Born in England	-1.600	-5.14
Born in Ireland	-1.013	-3.67
Born in Germany	-0.858	-2.29
Born in Scotland	-0.502	-0.97
Born in Other Foreign Countries	-1.949	-2.39
Native-born Migrants Across Counties*	0.013	0.06
Native-born Migrants Across States	0.448	2.45

Note: The intercept reflects the height of a farmer or professional who was born, and resides, in a rural area of New England. Many observations lacked information on one or more of the characteristics covered by dummy variables. In such cases(for example, the urban or race dummies), they were assumed to take on zero values for the variables. This procedure tends to bias the regression coefficients toward zero.

*This dummy variable refers to those recruits who migrated across counties within a single state.

do not accurately reflect the populations of their home countries, since many of them probably arrived in America before reaching terminal height. Their height would lead to an underestimate of the differences between the stature of Americans and those of European populations. Of particular interest are the coefficients for the three major immigrant groups, the English, Germans, and Irish; the English are reduced in height by well over an inch, relative to New Englanders, the Irish by about 1.0 inches, while the German-born are shorter by 0.9 inches. The relative sizes of these coefficients are influenced by the conditions in the home country, the average ages of immigration, and the conditions within the states that attracted these ethnic groups. It should be noted that the coefficient for those foreign born who are farmers is a relatively large -0.8 inches, and statistically significant. One should take account of these occupational dummy variables when comparing categories of native and foreign born. This example of farmers would imply that rural New England-born farmers were 1.8 inches taller than rural Ireland-born farmers. It is also interesting that, while southern-born non-whites are reduced 1.7 inches in stature relative to whites, the advantage of northern whites over non-whites is not statistically significant.

The regression coefficients suggest that the level of nutrition may have varied between urban and rural areas, both in the U.S. and Europe. Although the difference may simply reflect differences in the economic background of the two classes of immigrants, foreigners who were identified as having been born in urban centers were nearly an inch shorter than those who were not.[25] This relative circumstance of the urban born did not vary across foreign countries. As for individuals born in American urban areas, it is not clear that their stature was different from that of their rural-born countrymen. Despite the negative coefficient on the dummy variable for urban-born natives, the lack of statistical significance seems to undercut notions of

inferior nutritional and other environmental conditions in cities.[26] The effect of residing in urban areas, however, is estimated to have been a reduction of approximately 0.9 inches in final height, and appears to have been confined to the native born. The coefficient, significant at the 10% level, when viewed together with our evidence on patterns of migration, may indicate that those who were malnourished when growing up (and perhaps more likely to be poor) tended to become concentrated in urban areas. It might also be understood as reflecting the effects of conditions prevailing in cities on height, but such an interpretation would depend upon these residents moving to the cities at a young age, or a large proportion of the urban born departing from these areas at early ages. The high rate of out-migration from urban areas makes the latter possibility seem quite plausible, as it could obscure the impact of living in an urban environment. Yet, the finding that the urban-born natives were not significantly shorter than their rural-born peers, would seem to tip the weight of the evidence against the argument that the nutritional circumstances and physical conditions they faced in pre-revolutionary American cities were relatively worse. It may be the case that the poverty and suffering that has been perceived amidst the urban classes of the era, was at least partially the consequence of the attraction of cities to the less fortunate segments of the population.[27]

Finally, the lack of significant coefficients on the occupational class dummy variables is quite striking. The small coefficients, and their insignificance, imply that the level of nutrition did not vary substantially over occupational, and perhaps income, classes. This may be indicative of the extent of economic equality, at least within a colony or region. If income is more closely related to region than to occupation, then our regional difference in heights may reflect a degree of income inequality. Of course, it is important to remember what underlying phenomena we are attempting to detect.

The heights of individuals are influenced by the levels of nutrition they experience when they are young. Thus, we might prefer to know the occupations of the parents of these soldiers when investigating the relationship between occupation and nutrition. The greater the extent of social mobility, the less one would expect to observe a relation between an individual's occupation and his height (unless occupation was a function of height). Another reason why the occupational categories may not explain much of the variation in height is that they are not sufficiently precise. For example, our inability to distinguish between large planters and yeomen with minor holdings may be the critical element in achieving our result.

Another interesting finding that emerges from the regression analysis is the relationship between migratory behavior and height. Those native-born soldiers who migrated from their places of birth to reside or enlist in other colonies were nearly half an inch taller than their more sedentary neighbors. Movement across counties, but within states, was not associated with any advantage in height. It is unclear whether the greater stature is attributable to superior material circumstances of those who migrated or the net effect of migration to areas with better nutritional conditions. However, since only long-distance migrants were taller than others, the result might seem to suggest, particularly when viewed in conjunction with the implied character of urban-rural movement, that the relatively well-to-do were more likely to migrate. This interpretation is supported by the observation of the pattern, revealed by these data, that rates of migration to another state were rather low until age 20, when most individuals have virtually achieved final height. Other evidence that bears against the argument that the height advantage of migrants is a consequence of better nutritional conditions in recipient areas was provided by the finding that the northern born who migrated to the south, an apparently superior region with respect to environmental factors affecting height, were no taller than those who migrated to other colonies within the North. Regression coefficients

on this special class of migrants were small, and not statistically significant, as were the coefficients on foreign born in the South.

A regression with a similar specification run over the French and Indian War sample is reported in Table 3. Although many similarities are apparent, the patterns that emerge are often rather different from those of the later period. The native born are again of substantially greater stature than the foreign born, by approximately one to two inches. The variation in the heights of recruits across states, however, is more difficult to estimate, because of the very large portion of the sample being drawn from New York. All of the New England-born recruits had migrated across state lines and thus some of the qualitative results regarding inter-state comparison are sensitive to the inclusion of the migration dummy as an independent variable. The finding that New Yorkers are taller than recruits born in other states is not sensitive to the specification of the regression. However, the evidence that the height of Virginians also exceeded those of New Englanders does depend upon the allowance for migratory status. There are no other indications of significant differences in stature across states. The striking result already referred to is that those native born who had migrated out of their home state were a remarkable 0.85 inches taller than those who had not. The unrepresentative composition of the sample might lead to doubts about the validity of the finding, but the size and significance of the coefficient, as well as its consistency with the Revolutionary pattern, bolster its legitimacy.

The results from the French and Indian War sample deviate from those of the Revolutionary sample in several important respects. First, there appears to be no significant relation between height and birth or residence in an urban area.[28] This may not be surprising for American cities, since they were still small and relatively underdeveloped at the beginning of the 18th century, but the absence of any effect for foreign urban centers is unexpected.

TABLE 3

REGRESSION WITH HEIGHT AS DEPENDENT VARIABLE

RECRUITS FROM FRENCH AND INDIAN WAR

AGES 24-35

R^2= 0.1338 N = 3057

Variable	Coefficient	t-statistic
Intercept	67.555	142.59
Years of Age	-0.001	-0.10
Native-born Artisan	-0.591	-2.55
Native-born Laborer	-0.584	-2.40
Foreign-born Artisan	-1.048	-3.66
Foreign-born Laborer	-1.006	-3.47
Foreign-born Farmer or Professional	-0.785	-2.20
Seaman	-0.613	-2.01
Unknown Occupation	-0.560	-1.90
Born in Native Urban Area	-0.120	-0.45
Born in Foreign Urban Area	-0.445	-1.53
Urban Resident	-0.488	-1.61
Foreign-born Urban Resident	0.452	1.36
Non-white	-1.043	-3.33
Born in New York or New Jersey	1.022	3.97
Born in Pennsylvania or Delaware	0.074	0.24
Born in Maryland	-0.246	-0.44
Born in Virginia	0.581	1.88
Born in North or South Carolina	0.223	0.16
Others Born in America or Canada	0.546	0.85
Born in England	-0.709	-3.22
Born in Ireland	-0.116	-0.58
Born in Germany	-1.067	-4.86
Born in Scotland	-0.334	-1.15
Born in Other Foreign Countries	-0.331	-0.47
Foreign Born Residing In South	-0.595	-3.02
Native-born Migrants Across States	0.846	3.29

Note: Same as to Table 2.

Another point of divergence is that the occupational dummy variables provide significant explanatory power in accounting for the variation in height across individuals. Both native-born artisans and laborers were about 0.6 inches shorter than native-born farmers, after adjusting for the urban-rural mix and other factors. It is not at all apparent why occupation is related to the height of native born in this sample, but not in the Revolutionary sample. The above discussion noted that, the greater the degree of social mobility, the weaker the link between the two variables. Thus, one might argue that social mobility increased during the inter-war period. An alternative view might identify the relative geographical homogeneity of the French and Indian sample, with its implications for consistent recording of occupations, as the critical element. Although this interpretation is not without appeal, the answer does not seem completely adequate, since one would expect a significant regression coefficient if, by all colonies of birth, laborers were shorter than farmers (a not especially stringent condition). A third explanation is that regional differences dwarfed the occupational effects in the later period, and the migratory behavior must be given more attention before the relationship between occupation and height can be isolated. None of these scenarios is very satisfying, however, and this issue deserves further study.

Although the above regressions are extremely informative about the variation of height in cross-section, we also seek to investigate changes in stature over time. For this purpose, we ran a regression over all of the recruits, ages 25 to 44, from the French and Indian and Revolutionary samples. In this regression, the results of which are reported in Table 4, the intercept represents the height of a white farmer, who was born in rural New England, lived in a rural area, and served during the Revolutionary War. We have already discussed how some of the estimated relationships shifted significantly during the inter-war period (or, more precisely, over the two samples). For those

TABLE 4

REGRESSION WITH HEIGHT AS DEPENDENT VARIABLE

RECRUITS FROM BOTH WARS

AGES 24-35

R^2= 0.1365 N = 4842

Variable	Coefficient	t-statistic
Intercept	67.936	199.41
Years of Age	-0.006	-0.59
Native-born Artisan	-0.237	-1.62
Native-born Laborer	-0.244	-1.41
Foreign-born Artisan	-0.723	-3.97
Foreign-born Farmer or Professional	-0.918	-3.93
Seaman	-0.272	-1.27
Unknown Occupation	-0.220	-1.41
Born in Native Urban Area	-0.150	-0.67
Born in Foreign Urban Area	-0.656	-3.18
Urban Resident	-0.608	-2.37
Foreign-born Urban Resident	0.616	2.16
Non-white	-0.862	-3.45
Southern Non-white	-0.843	-1.56
Born in New York or New Jersey	0.788	5.43
Born in Pennsylvania or Delaware	0.103	0.49
Born in Maryland	0.215	0.77
Born in Virginia	0.610	3.85
Born in North or South Carolina	0.855	2.60
Others Born In America or Canada	0.183	0.65
Born in England	-1.215	-7.23
Born in Ireland	-0.555	-3.66
Born in Germany	-1.243	-7.05
Born in Scotland	-0.663	-2.73
Born in Other Foreign Countries	-1.080	-2.05
Native-born Migrants Across States	0.462	4.49
Served During French and Indian War	-0.296	-3.03

Note: Same as to Table 2.

variables where there was a dramatic change, a literal interpretation of the size of the coefficient would be misleading, since it will, for the most part, only reflect the average impact of the variable. In other cases, the combined sample may yield improved estimates of the effects of variables, since there are more observations.

The regression was primarily designed to determine, after adjusting for all of the relevant factors we can, the amount of increase in the final heights of various groups between the wars.[29] Although comparisons of the Quantile Bend estimates have the advantage of being adjusted for the biases associated with truncation and heaping, they do not account for the influences of other factors which might have varied over region or time. The coefficient on the dummy variable for serving in the French and Indian War indicates that the mean terminal height of recruits increased approximately 0.3 inches between the wars. Other regressions provided some evidence that southerners, non-farmers, and foreign born grew somewhat more and northerners and farmers a bit less, but these differences failed the test of statistical significance. Thus, the results imply that Americans in general were growing at a respectable, but not unusual, rate of 0.5 inches per generation. Multivariate analysis does subtly alter the qualitative findings in that the gap in the rates of increases between the North and the South, suggested by the comparison of Quantile Bend estimates, is closed. The absence of rapid growth should not obscure an important feature concerning U.S. height. By the time of the Revolution, American stature (of adult males) exceeded that of Europeans by a remarkable two to four inches, and had virtually achieved the level prevailing one hundred and seventy years later.[30] Both in terms of stature and nutrition, Americans may not have had as much room for advance.

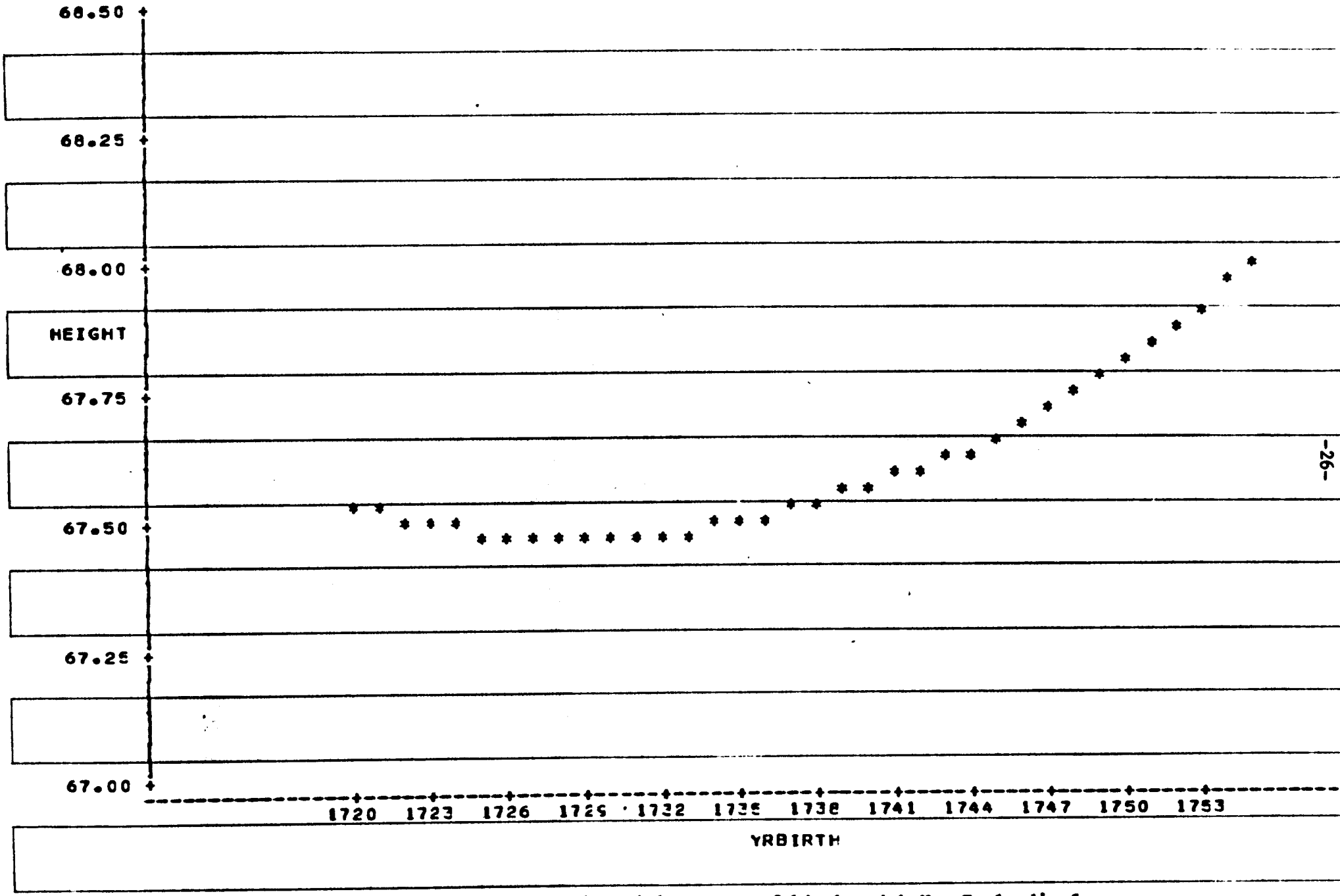
In addition to this approach of employing dummy variables to analyze the variation in height between the two periods, we have also attempted to estimate non-linear, continuous trends over time in stature, or in the influence of

independent variables. Regression analysis was conducted over the sample of native born, ages 25-44, from both the French and Indian and Revolutionary War samples. Estimation of such time trends is complicated by the relatively small number of observations. In Figure 3, we present a plot of the trend in the stature of rural New Englanders by year of birth. While the absolute level of height reflects that of New Englanders, the time trend represents the native born in general, as no sub-group tested appeared to have a statistically different path. This plot of regression results indicates that the stature of the native born was stable for the cohorts born from 1720 to approximately the 1740s, but that afterwards there was a rapid increase in heights through the cohort born in 1755. The sudden growth after 1740 may appear suspicious. However, it should be noted that even during the apparent fifteen year spurt, the implied growth rate was not at all unreasonable or exceptional. As for the dating of the change, McMahon has also found dramatic improvements in the New England diet during these two decades.[31] An F-test of the time trend implies statistical significance at the 5% level. Although not statistically significant, other evidence suggests that for the cohorts born in the mid-1720's through the mid-1750's there may have been a cycle in the stature of laborers, with the trough occurring at the cohort of 1740. This finding is consistent with, or possibly an artifact of, the systematic variation in height across occupation in the French and Indian sample, and the absence of such a pattern in the Revolutionary sample.

As we discussed above, there is a possibility that our results are affected by sample selection bias. Although a preliminary examination of the distribution of heights suggested that any truncation or shortfall that might have occurred is probably of a minor magnitude for native-born groups, it should be noted that such problems with our sample would be likely to produce underestimates of the differences in mean terminal heights between groups.

FIGURE 3

THE TREND OVER TIME IN AMERICAN TERMINAL HEIGHTS*

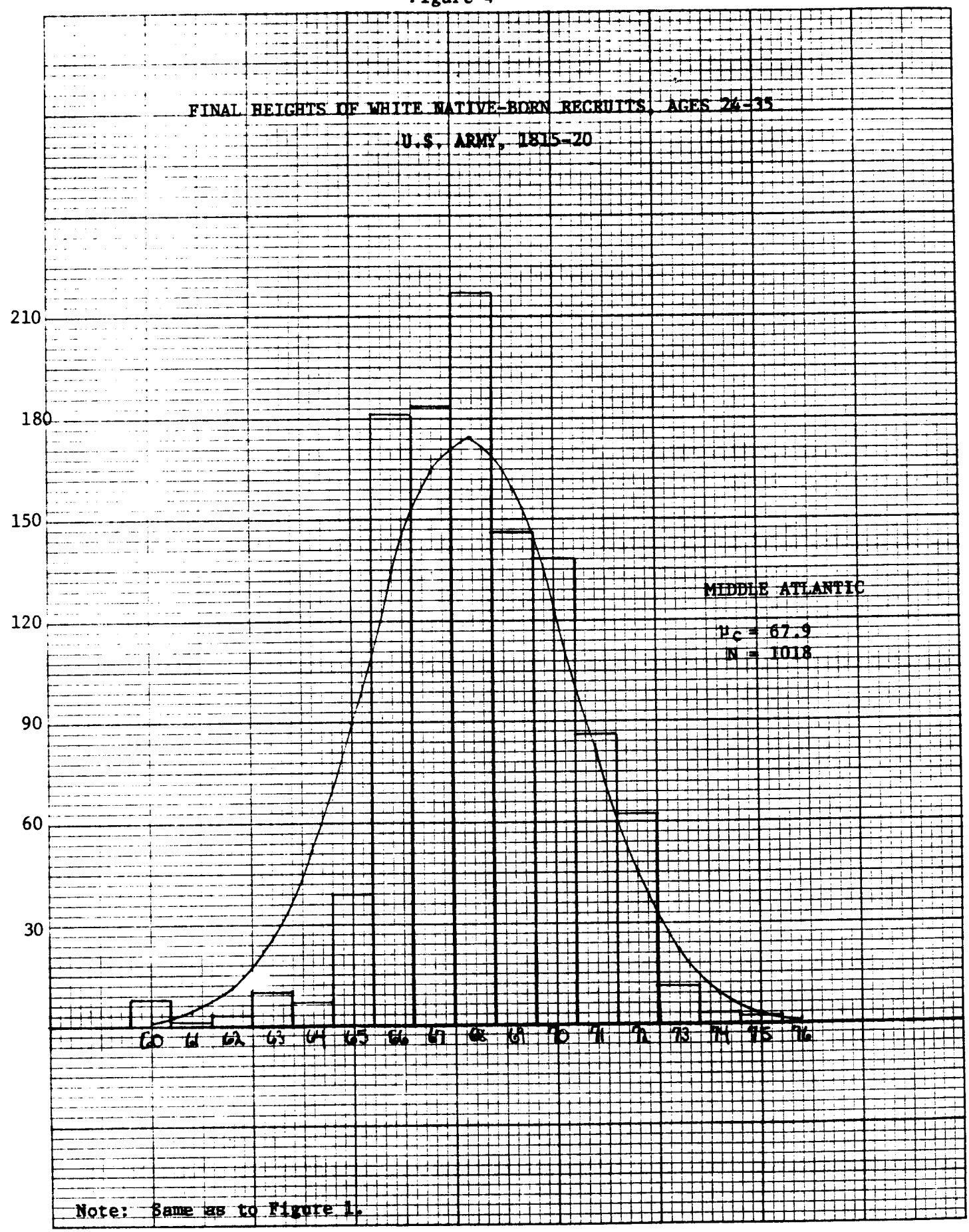


*Estimated for cohorts, using a 4th degree polynomial on year of birth, with New England's farmers as the base group.

This conclusion would apply if the truncation decision based on height was applied equally across sub-populations and if all of these groups were characterized by the same degree of dispersion in heights. Both of these conditions would seem to be reasonable assumptions and would tend to imply that the regression coefficients would be biased toward zero. If truncation occurred below some specific level of height, then the sample means of terminal heights of all sub-populations would be biased upwards as estimators of the true population values. However, the bias associated with the sample means would be greater for the shorter groups, because larger proportions of their distributions would be subject to truncation (the argument is similar for right-tail truncation). Therefore, analysis of the unadjusted heights will be likely to yield lower-bound estimates of the differences in stature between groups. The coefficients in our regressions are thus underestimates of the effects (in absolute value) of the respective variables, implying that the significant differences observed are not simply consequences of this type of sample selection bias.

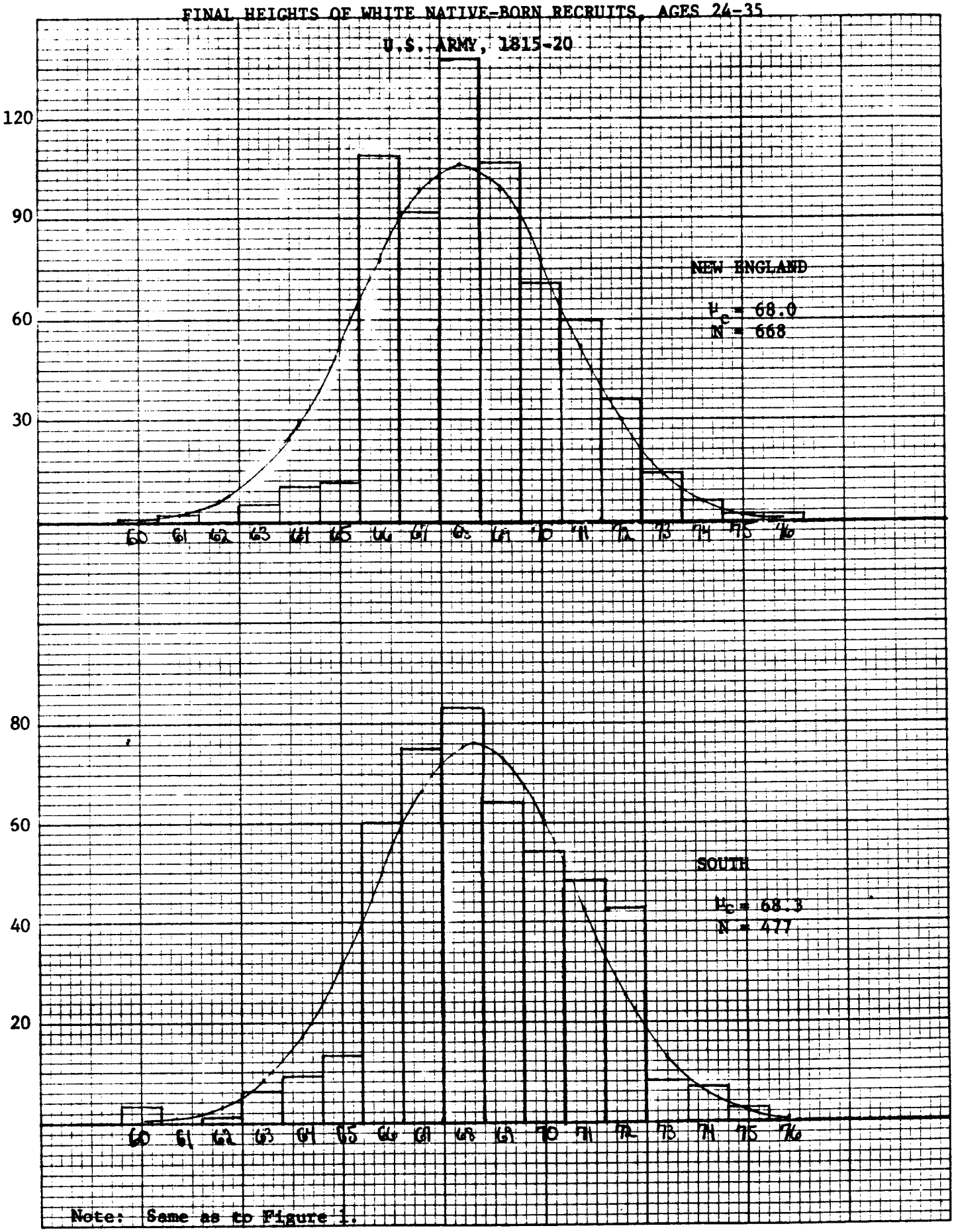
Although we were fortunate in that the native born groups in the colonial sample were not significantly affected by this type of sample selection bias, this was not the case with our sample from the U.S. Army of 1815-1820. As mentioned above, the soldiers of this peacetime force were already far from representative of the general population, at least with regard to their occupational structure. In addition, the distributions of final heights (as shown in Figure 4 and 5) for the three regional groups reveal that the minimum height requirement of 65 inches was enforced to some degree. The resulting shortfall on the left tail of the distribution is also accompanied by a "heaping" of recruits at 66 and 67 inches, just above the height limit. Accordingly, the unadjusted means of these distributions should be upward biased estimates of the

Figure 4



Note: Same as to Figure 1.

Figure 5



Note: Same as to Figure 1.

true means. This judgement seems confirmed by the application of the Quantile Bend Method yielding estimates of the regional final heights that fall an average of 0.2 inches below the unadjusted figures. (see Figure 4 and 5). These estimates are striking for their close resemblance to regional final heights of Revolutionary troops. On average, there was no growth in the stature of native-born Americans between the two periods. Despite increases in European heights, however, Americans appear to have maintained at least a two inch advantage over their peers across the Atlantic.[32]

Multivariate analysis also tends to indicate that the patterns of variation in heights observed during the Revolutionary period generally persisted through the second decade of the nineteenth century (see Table 5). After controlling for occupation and other measurable variables, southerners are again the tallest of the recruits.[33] Some of the estimated correlates with height, however, are strengthened, if not altogether new. For example, birth in urban areas is now strongly associated with a diminution in stature, as is lower occupational status.[34] As was argued above, truncated distributions would be expected to bias regression coefficients toward zero. This might account for the relatively small coefficients and t-statistics in this regression. It might also constitute a partial explanation of the lower R^2, relative to the regressions on the earlier samples, since the truncation affects the shorter groups more than the tall the relative amount of systematic variation around the mean is decreased.[35]

Despite the disproportionate shortfall among the shorter groups, regression analysis detects a number of statistically significant differences between classes of recruits. The foreign-born coefficients are all negative and large. While some are only of marginal significance, this is largely attributable to multicollinearity with the foreign-born occupation interaction terms. If either set of variables is excluded from the regression, the t-statistics for the other increase substantially. On average, the foreign born appear to be one

TABLE 5

REGRESSION WITH HEIGHT AS DEPENDENT VARIABLE

RECRUITS FROM U.S. ARMY, 1815-20

AGES 24-35

R^2= 0.0594 N = 3696

Variable	Coefficient	t-statistic
Intercept	67.858	176.86
Years of Age	0.027	1.91
Native-born Professional	-0.073	-0.23
Native-born Skilled Worker	-0.148	-1.22
Native-born Unskilled Worker	-0.254	-1.85
Native-born Seaman	-0.661	-3.03
Foreign-born Farmer or Professional	-0.136	-0.30
Foreign-born Skilled Worker	-0.580	-1.36
Foreign-born Unskilled Worker	-0.365	-0.86
Foreign-born Seaman	-1.153	-2.33
Unknown Occupation	-0.166	-0.45
Born in New York or New Jersey	-0.085	-0.70
Born in Pennsylvania or Delaware	-0.227	-1.79
Born in Maryland or D.C.	-0.243	-1.42
Born in South	0.302	1.87
Born in West	-0.116	-0.31
Born in England or Scotland	-0.716	-1.62
Born in Ireland	-0.727	-1.71
Born in Other European Countries	-1.726	-3.78
Born in Other Foreign Countries	-0.741	-1.53
Born in Native Urban Area	-0.495	-4.12
Enlisted In Urban Area	-0.092	-0.97
Foreign Born and Enlisted In Urban Area	0.158	1.07
Born in U.S. Before 1786	-0.116	-0.68
Born in U.S. During 1786-90	-0.119	-1.02

Note: The intercept reflects the heights of a farmer who was born, and enlisted, in a rural area of New England

to two inches shorter than the natives. The impact of birth in urban areas is also very significant, reducing the height of a native recruit by 0.5 inches. Caution is required, however, in the interpretation of the coefficient on urban enlistment. As there was generally only one enlistment center per congressional district, the place of enlistment is an especially crude proxy for residence. It is not surprising that it proves to be unrelated to height.

The stature of recruits also varied systematically over occupational status. Among both native and foreign born, farmers appear to have been somewhat taller than artisans or laborers, with seamen being the shortest occupational class. The discrepancies between groups are not as great as those estimated for the French and Indian sample, perhaps because of the truncation problem, but they do diverge from the Revolutionary finding of no significant differences.[36] The relationship between migratory behavior and height has also shifted to some degree. Although not included in the regression presented in Table 5, regression analysis has indicated that natives who moved across state lines were generally 0.25 inches shorter than their counterparts who remained in their home states. Only New Englanders maintained the Revolutionary pattern of inter-state migrants being taller (in this case, 0.3 inches). Both of these coefficients are quite significant, as well as puzzling.[37]

Conclusions

By the time of the Revolution, Americans seem to have approached modern heights. Even more startling is the finding that cohorts born as early as the 1720s had nearly achieved such stature. During the generation just preceding the Revolution, the mean terminal height of Americans was increasing at a somewhat slower rate than that of the British, 0.5 inches per generation to 0.8 inches, but maintained a two to four inch advantage over European populations. American stature appears to have then stabilized through 1820. Despite the traditional suspicion that the living standard of the bulk of the American population during this period exceeded that of the respective group in England,

the suggested extent of American superiority in nutritional conditions is remarkable. The English did not achieve the same level in stature until the 20th century.[38]

The national average necessarily obscures the diversity of nutritional circumstances experienced by different segments of the population. Yet, one of the implications of the analysis is that the differences across social classes, with the exception of the foreign born, in nutritional status were not very large. Even urban laborers were well nourished, especially by European standards. Regardless of the existing degree of inequality with respect to income or wealth, the nutritional value of the diet does not appear to vary substantially over social (occupational or urban-rural) class. Nevertheless, there are some indications that disparities in stature between groups were widening over time. Such a finding might provide some support to adherents of the view that inequality in the U.S. was growing during this period. The evidence, however, consists primarily of the increasing differences in heights between the rural and urban born. Although occupational status went from being unrelated to stature among Revolutionary recruits to being significantly related among U.S. army troops, there was no consistent secular trend in the importance of this variable.

Another socioeconomic attribute that is strongly associated with height is migratory behavior. In both the French and Indian War and Revolutionary samples, recruits who had migrated across state borders were significantly taller than non-migrants. There was no height advantage associated with soldiers who had merely traversed county lines. These results may reflect the greater need for resources that long-distance migration imposed.[39] Migratory behavior is also systematically related to stature among the troops in the 1815-20 sample, although the pattern observed is somewhat puzzling.

The pattern of U.S. regional variation in height appears quite durable. In each of the colonial samples, New England and the Middle Atlantic are quite

similar on average, with New Yorkers and New Jerseyans being taller than other natives from these regions, after holding constant all other factors. Southerners seem to have gained a significant advantage in height just after the French and Indian War and maintained it until the present day. The issue of what these apparent differences in nutritional status reveal about relative income levels is especially intriguing. At the stage of economic development which characterized early America, one might expect that the consumption of food would be a good indicator of the standard of living. However, even if one disregards the possibility of dissimilar tastes, different conditions of food supply, reflected in relative prices, might provide an alternative explanation to differences in per capita income.

In the case of the North and the South, the obvious difference between the agricultural sectors of the regions, such as in crop mix or seasonal patterns, could generate some discrepancies in nutrition apart from income. In addition, there are other factors which could influence the demand for food in specific areas and thus affect the nutritional status of the populations involved. One of many candidates for such an agent is climate; in the South, warmer temperatures may have encouraged greater consumption of meat or protein. Differences in the levels of energy utilizing activities might also generate disparities in height unrelated to the absolute amounts of food intake. Another possibility is that amidst the virulent disease pool of the South, individuals with a taste for, or access to, highly nourishing diets would have lower mortality, biasing the mean terminal height upward as an estimate of the general population's level of nutrition, and if such tastes are conveyed to the next generation, natural selection would promote the evolution of a new set of preferences toward food. As the greater stature of southerners appears

to have endured, to some degree, for two centuries, one must favor the explanations which rely on phenomena other than per capita income.

Although the ostensible difference in the levels of nutrition between regions probably reveals little about levels of income, it may have substantial implications for the study of mortality during this era. The eighteenth and early nineteenth centuries were characterized by the narrowing of sharp interregional differences in mortality rates between New England and the South.[40] Crude mortality rates in Massachusetts appear to have remained in the 15 to 25 per thousand range throughout this period, while the rates for whites in the South declined from roughly 50 per thousand to the vicinity of 25 per thousand.[41] The higher mean terminal heights in the South would tend to dispel the notion that the southern mortality rates were linked to lower levels of nutrition in that area. The data raise the possibility that the apparent southern advantage in nutrition may have worked to close the gap between the regional death rates by counteracting some of the factors which contributed to producing higher mortality in the South (disease pool, climate, etc.).

One might also consider the significance of the evidently high level of nutrition in America as a whole. Together with the regional patterns discussed above, this piece of evidence would seem to support the hypothesis that other factors besides nutrition were important in accounting for the significant decline of national mortality rates during the nineteenth century. Although there may have been additional improvements in nutrition during the period that simply failed to substantially boost final heights, the observation that Revolutionary Americans had achieved a stature unequalled by the English until the twentieth century dramatizes the rather high nutritional base upon which the society was building. Given the virtual equivalence of early twentieth century mortality rates between the two countries, it appears doubtful that such

advances served to greatly lower national death rates,[42] though their effects might just have been counteracted by other conditions or developments that had deleterious impacts on relative American mortality. It seems likely, however, that the superior levels of nutrition in America provide at least a partial explanation of the low mortality rates and high fertility rates, relative to Europe, which characterized the early U.S. demographic experience.

FOOTNOTES

1. Herman Freudenberger and Gaylord Cummins, "Health, Work, and Leisure Before the Industrial Revolution," Explorations in Economic History, 13 (January, 1976), p. 1-12.

2. For an early laboratory study, see A. Hays et al, The Biology of Human Starvation, 2 vols., Minneapolis, 1950. Examples of the recent concern of development economists are: Samir Basta and Michael Latham, "The Relationship of Nutrition and Health to Worker Productivity in Kenya," Technical Memorandum #26, World Bank Transportation Department, May 1977; or Darwin Keryadi and Samir Basta, "Nutrition and Health of Indonesian Construction Workers", World Bank Working Paper #152, April 1973. H. Kraut, "Food Intake as a Factor of Production," in Alimentation a Travail, eds. G. Duby and R. Bleyer, Paris, 1972.

3. Brown, Higgs, McKeown, and Record have emphasized the importance of nutrition as an explanatory factor, while Appleby and Razzel are among the most prominent critics of that view. Thomas McKeown, R.G. Brown and R.G. Record, "An Interpretation of the Modern Rise of Population in Europe," Population Studies, 26 (November, 1972), p. 345-382. P.E. Razzell, "An Interpretation of the Modern Rise of Population In Europe - A Critique," Population Studies, 28 (March, 1974), p. 5-17. Robert Higgs, "Mortality In Rural America, 1870-1920: Estimates and Conjectures," Explorations In Economic History, 10 (Winter, 1973), p. 177-195. Andrew Appleby, "Nutrition and Disease: The Case of London, 1550-1750," Journal of Interdisciplinary History, 8 (Summer, 1975), p. 1-22.

4. The study of human growth, utilizing height-by-age data, can be traced back to the early nineteenth century. Many of the scholars of this period linked differences in height-by-age profiles to socio-economic factors. See, for example, A. Quetelet, Sur l'homme et le developpement de ses facultes, ou: Essai de Physique social; Paris, 1835. M. Dunant, De la taille moyenne des habitants du canton de Geneve; Geneve, 1867.

5. Phyllis Eveleth and James Tanner, Worldwide Variation In Human Growth; London, 1976. James Tanner, "Growth at Adolescence," Blackwell Scientific Publications; Oxford, 1962. James Tanner, Fetus Into Man: Physical Growth From Conception to Maturity; Cambridge, MA, 1978. J.G. Fleagle, K.W. Samonds, and D.M. Hegsted, "Physical Growth of Cebus Monkeys, cebus albifrons, During Protein and Calorie Malnutrition," American Journal of Clinical Nutrition, 28 (1975), p. 246-253. M. F. Elias and F. W. Samonds, "Protein and Calorie Malnutrition In Infant Cebus Monkeys: Growth and Behavioral Development During Deprivation and Rehabilitation", American Journal of Clinical Nutrition, 30 (1977), p. 355-366.

6. There are several well documented cases of rather continuous secular increases in final heights. See. J. C. Van Wieringen, "Secular Growth Changes," Human Growth, vol. 1, eds. F. Falkner and J. M. Tanner; New York, 1978. However, there is some evidence that the long-term record of change in U.S. heights manifests cycles of substantial duration. See Robert W. Fogel et. al., "The Economic and Demographic Significance of Secular Changes In Human Stature: The U.S. 1750-1960," Unpublished manuscript, 1979.

7. There are some differences between ethnic groups in height-by-age profiles, but the relative importance of genetic and environmental factors remains in dispute. Although the differences, between well-fed blacks and whites, in the tempo of growth are substantial, the two groups have essentially the same mean final height. Although Orientals seem to have lower final heights than Africans or Europeans, the difference has diminished in recent years. See Eveleth and Tanner, Worldwide Variations In Human Growth.

8. F. S. Hulse, "The Breakdown of Isolates and Hybrid Vigor Among the Italian Swiss," Proceedings of Twelfth International Congress of Genetics, 2 (1977), Tokyo: Science Council of Japan.

9. Fred Anderson has been analyzing the information contained in these muster rolls, as part of his study of the impact of the French and Indian War on the Colony.

10. There have been several attempts at estimating the size of the American army during the War, but their range is wide and none of them is without problems. In 1790, Henry Knox, the Secretary of War, reported that there had been 396,000 total enlistments in the Continental Army and state militias during the War. This figure is recognized as grossly overinflated as a measure of the number of individuals involved because of multiple enlistments and the practice of meeting recruitment quotas by entering imaginary citizens on the rolls. The 184,000 - 250,000 estimate compiled by the Department of Defense, and cited by Historical Statistics, was intended to apply to the number of different individuals who served in the "army, navy, and marine corps." Assuming that the state militias are included in this estimate, the inclusion of naval and marine forces may make the Department of Defense numbers inappropriate for our purpose of determining the number in the militia or Continental Army. Two scholars, Howard Peckham and Don Higginbotham, have studied this question in some depth, and characterize the Department of Defense figures as too high. Since the methods by which the estimate was calculated are not shown, their criticisms are based on inferences about what the total enlistment of individuals could reasonably have been, given the size of the population. Both Peckham and Higginbotham (see Chapter 15 of Higginbotham, TheWar of American Independence, (New York, 1971), and Peckham, The War for Independence, (Chicago, 1958), p. 200.

acknowledge the lack of reliable information about the American colonial population. They begin their treatments with the 1790 census figure of 3,000,000 and the British American Department estimates of 2,500,000. Peckham notes the adjustments and deductions that are implied by the age distribution, the numbers of blacks and women, loyalists, etc., and concludes that only about 100,000 different individuals served in any of the militias or the Continental Army. He supports this claim with the argument that there were never more than 30,000 in arms at any one time. Higginbotham seems to offer a qualified endorsement to Peckham's estimate, but also indicates that the true number could conceivably range as high as 250,000.

The lack of information about the Department of Defense estimate is unsettling, but the 100,000 figure of Peckham's might seem low. A conservative accounting of the Massachusetts Soldiers and Sailors of the Revolutionary War, (Boston, 1896-1908) volumes would indicate somewhere between 100,000 and 140,000 individuals in Massachusetts alone with many recruits being drawn from Maine and New Hampshire. It is unlikely that adjustment for the number of sailors, as well as other upward biases in counting, could reduce the total figure significantly below 90,000. A 90,000 figure would seem quite plausible as estimates of the Massachusetts population during the Revolution are in the 290,000 - 307,000 range, with the inclusion of Maine increasing the total by 50,000. In an essay appearing in Legacies of the American Revolution, edited by Larry R. Gerlach et al., John Shy cites an unpublished estimate by Theodore J. Crackel as the best estimate he is aware of. Crackel produced a figure calculated with conservative assumptions of 185,000 individuals who served for at least six months in the American forces.

11. The only quantitative estimate that we have located is contained in Adam Seybert, Statistical Annals, Philadelphia, 1816, p. 631.

12. From the theory of genetics, one would expect terminal height to be normally distributed within a population, the members of which had experienced the same environmental conditions. Quetelet, Tanner, and Van Wieringen, among many scholars, have noted the empirical regularity of distributions of terminal height being approximately normal. See James Tanner, "Boas's Contributions to Knowledge of Human Growth and Form," American Anthropologist, 1, no. 5, Part II, 1959.

13. The Quantile Bend estimator that we have chosen to employ in this paper begins by estimating the amount and extent of shortfall (or truncation) from the bending of quantile-quantile probability plots. Assuming the estimated shortfall, a quantile plot is then fitted by regression. The estimated line provides our estimates of the mean and standard deviation of the underlying distribution. The theory and method of the Quantile Bend estimator, as well as of alternative estimators, are described in Kenneth W. Wachter and James Trussell, "Estimating Historical Heights," Unpublished manuscript, 1980. and in the Statistical Appendix to Fogel et. al., "The Economics and Demographic Significance of Secular Changes in Human Stature: The U.S. 1750-1960."

14. In this paper, the term truncation is used to refer to several related, but distinct, phenomena. Normally, truncation would be said to occur if, in the present context, no one under five feet and six inches was allowed to enlist. The resulting distribution of the final heights of the recruits would resemble a normal distribution until the selected level of stature, where the number of observations would suddenly fall to zero. The type of truncation evident among the actual recruits is less complete. Instead, the height limitation was enforced in an irregular fashion, with only a portion of the shorter recruits being screened out. In our usage, truncation encompasses this pattern as well. We also adopt the term "shortfall" to refer to the general phenomena of observing fewer individuals at some levels of stature (essentially the left tail), than would have been expected if the sample distribution was normal.

15. There are two different sources of height-by-age data for northern Civil War recruits that we have consulted. Both imply, or have already calculated, a mean terminal height of 68.2 inches. See J.H. Baxter, Statistics, Medical and Anthropological, of the Provost Marshall General's Bureau..., U.S. War Department, 2 vol.,; Washington D.C., 1875. and B.A. Gould, Investigations in the Military and Anthropological Statistics of American Soldiers; Cambridge, MA, 1869.

16. The mean final height for the U. S. as a whole, at the time of the Revolution, is estimated as 68.1 inches using either of two methods. Under the first, the regional estimates are weighted by the number of observations per region in the Revolutionary sample, and an average computed. The other procedure also calculates a weighted average of the regional estimates, with the regional population figures for 1790 serving as the weights.

The mean final height of native-born whites during World War II has been estimated as 68.2 inches (Fogel et al., "The Economic and Demographic Significance of Secular Changes In Human Stature..."). Since that time, there has been additional growth and the current figure appears to be in the 69.0 to 70.0 range. Thus, while Revolutionary Americans had virtually achieved World War II level stature, their height falls significantly below the contemporary level. It is clear that they had not exhausted their genetic potential for final heights.

17. In his stimulating discussion of colonial nutrition, James Henretta cites this quotation, but argues that the relative scarcity of livestock increased over the course of the 18th century. He further implies that this scarcity was most severe in New England. Although it is a reasonable hypothesis, the evidence he offers in support of the former contention is highly sensitive to the selection of the base year. See his The Evolution of American Society, 1700-1815; Lexington, MA, 1973, p. 20. In her study of probate inventories from Middlesex County, Massachusetts, Sarah McMahon found strong evidence of substantial increases in meat consumption over the course of the 18th century. Sarah F. McMahon, "Provisions Laid Up For the Family: Toward a History of Diet In New England, 1650-1850," Unpublished manuscript presented at the Conference On Economic Growth and Social Change In the Early Republic, 1775-1860; April, 1980.

18. McMahon's work also suggests that there were dramatic changes in the composition of the diet during the 18th century. While consumption of meat and vegetables increased, that of grains declined.

19. The taller stature of the southerners, relative to both New Englanders and natives of the Middle Atlantic states, is statistically significant.

20. A potential bias of serious magnitude is the possibility that the recruits, or some subset of them, were measured with their shoes on. Although there is no evidence that any measurements were made in this manner, the problem is, nevertheless, deserving of attention. Unfortunately, while military manuals with instructions that measurements should be taken with shoes off have been discovered for later periods, none has been located for the French and Indian or Revolutionary War. Although evidence of this nature would be reassuring, an examination of the data leads to a discounting of the seriousness of the problem. Comparisons of the heights of foreign-born and black soldiers in our sample to those reported in other sources available for these groups, suggest that the muster roll measurements are extremely unlikely to have been made with the shoes on. Inferences can also be made from the heights of recruits who migrated across colonial borders. Only in South Carolina were such individuals, after allowing for the greater stature of migrants in general, significantly taller than their counterparts who had remained in the home colony. In this case, there is a considerable amount of impressionistic material describing the superior diet of the citizens of South Carolina; thus, the discrepancy in heights can be explained without resorting to shoes. As South Carolinians were only marginally taller than New Yorkers and North Carolinians, and shorter than Virginians, the proposition that the former group was unique in being measured with shoes on is not persuasive. We have also obtained information on individuals who enlisted, and thus were independently measured, more than once. These data were retrieved from muster rolls for New York during the French and Indian War and for Massachusetts during the Revolution. An anaylsis of those cases where there were two observations of a fully grown recruit, indicated that measurements were taken with a considerable degree of accuracy, but that errors were sometimes introduced through rounding. Although the errors may not have been random, a comparison of the mean heights of those measured to the fraction of an inch, with those who were not, revealed no significant difference.

This held true in general, as well as for the limited number of individuals who enlisted in different counties.

21. Lionel Chalmers, An Account of the Weather and Diseases of South Carolina; London, 1776, p. 37.

22. Our understanding of the geographical pattern of wealth holdings is based on the work of Alice Hanson Jones. For a summary of these findings, see U.S. Bureau of the Census, Historical Statistics of the U.S. Colonial Times To 1970; Washington D.C., 1978, Series Z 169-191.

23. Benjamin Gould, The Military and Antropological Statistics of American Soldiers.

24. Some rough computations for 1970, based on the Parnes samples, suggest that southerners remain significantly taller than northerners.

25. European cities that could be identified as having a population of greater than 20,000 at or near 1800, were classified as urban areas. Most of the foreign born did not report their city of birth. These recruits were treated as if they were born in rural districts.

26. The statistical significance of the coefficient on birth in native urban areas is sensitive to the sample over which the regression is run. Over recruits aged 24 to 35, the coefficient does not even approach statistical significance, but if the sample is expanded to include those aged 24 to 45, the coefficient is significant at the 90% level.

27. The reporting of places of birth and residence (or enlistment) enable one to examine the migratory behavior of the recruits. In both the French and Indian and Revolutionary War samples, we observe high rates of out-migration from urban areas among the native born. Netting the inflows and outflows of native Americans, the cities were losing population. That cities were apparently so unattractive, may have implications for the relative conditions of urban areas, as well as for the segments of the population that were located there. The effects of migratory flows are difficult to adjust for, but an appreciation of their importance may alter one's understanding of findings concerning the characteristics of urban residents. In recent years, scholars have increasingly focused on poverty in pre-Revolutionary cities. For examples of this development, see the articles by Gary Nash: "Poverty and Poor Relief In Pre-Revolutionary Philadelphia," William and Mary Quarterly, 33 (1976), p. 3-30 and "Urban Wealth and Poverty in Pre-Revolutionary America," Journal of Interdisciplinary History, 6 (Spring, 1976), p. 545-584.

28. When migratory status is included as an independent variable, urban residence has a marginally significant, negative effect on height. This association disappears when the migration variable is excluded from the regression.

29. The difference in average year of enlistment between the two samples is 19 years. We are thus comparing members of the same age groups two decades apart.

30. For example, the mean final heights of the British Royal Marines were estimated as 64.8 inches for the 1760s and 65.1 inches for the 1780s by Wachter and Trussell, "Estimating Historical Heights." Thus, the native American recruits maintained a three inch advantage over their British peers. The implied rate of increase of British final heights is 0.5 inches per generation, the same as that of the Americans. The mean final height of American males, during World War II, was estimated as 68.2 inches in Fogel et.al., "The Economic and Demographic Significance of Secular Changes In Human Stature."

31. McMahon's study suggests a substantial increase in the level of meat consumption, up to 1750, which then levels off until the 19th century. McMahon, "Provisions Laid Up for the Family: Toward a History of Diet In New England, 1650-1850."

32. Employing the Quantile Bend approach, Wachter and Trussell have estimated the mean final height by British Royal Marines as 65.5 inches for the decade 1800-1809. See their "Estimating Historical Heights."

33. We investigated the possibility of changes over time in height (cyclical), both for sub-groups and for the population over the cohorts born from 1776 to 1795. Although based on few observations, there is some evidence, however, that recruits born during and just after the Revolutionary War were of shorter stature. As cohort analysis failed to identify any secular trend or cycle in heights, the curious significance of the coefficient on years of age would seem to probably stem from misreporting of age.

34. The shift from urban residence, but not birth, being associated with height in the Revolutionary sample to urban birth, but not enlistment, in the later sample, seems at first perusal to be suspicious. Nevertheless, it is actually a quite reasonable result. As noted above, the severe problem with the reporting of the city of enlistment in the latter sample introduces so much noise into this variable that it might be expected to obscure an underlying relationship between urban residence and stature. In addition, the widening gap between urban and rural conditions that has been postulated by many scholars to have emerged during this period, is quite consistent with this set of findings.

35. Two points are to be made here. First, that truncation has a greater impact on the mean heights of shorter groups is supported by the observation that the Quantile Bend estimator diverged the most from the unadjusted means of the Middle Atlantic and New England distributions. The second is that much of the decline in the relative amount of systematic variation in the dependent variable, apparent in the lower R^2, seems attributable to the narrowing of differences between native and foreign-born heights.

36. One might be skeptical about this abrupt change in the pattern of variation in height. Although persuasive explanations can be constructed to account for such swings, it is possible that they are merely products of data problems. The most obvious area of concern is the possibility that the representativeness of those serving in the military, of their respective groups in the population as defined by the information available to us, may have fluctuated over time.

37. Although this result is also puzzling, it should not be surprising if the relative probabilities of a particular segment of the population migrating varied over time and place. The apparent association between nutritional status and migratory behavior will receive more intensive study in future work.

38. The claim that the British did not achieve a mean final height of 68.1 inches until the 20th century is based on the finding that they had only reached 67.4 inches by 1883. See Fogel et. al., "The Economic and Demographic Significance of Secular Changes In Human Stature." In comparing the heights of the two populations, it should be obvious that even if nutritional constraints inhibited Britain from industrializing earlier than it did, they could not have been binding on the U.S. Although the tall stature of the latter population might partially reflect a less energy-intensive regime of activities (primarily work-related), this factor seems incapable of accounting for the enormous disparity between the heights of the two populations.

39. Since the positive association between final height and inter-state migration is not sensitive, in the Revolutionary sample, to either the area moved from or migrated to, it would seem to be related to factors affecting the probabilities of choosing to migrate or of successfully completing the passage. Alternative explanations are available, but the most plausible interpretation would seem to be that those materially better off, and thus tending to be taller, would be more likely both to migrate and to complete (including survive) the migration. Presumably the greater the distance to be travelled, the greater the resources needed to make the journey. Of course, the decision to migrate is influenced by many other variables, some of which could also be associated with nutritional status. It might be argued that the enhanced stature of inter-state migrants is a result of the improved conditions they enjoy in their new locations. However, most of this class of migrants travelled at such an advanced age that it is doubtful that the new circumstances could have had a large impact on the final heights achieved.

40. Maris Vinovskis, "Mortality Rates and Trends In Massachusetts Before 1860" Journal of Economic History, 32 (March 1972), p. 184-213.

41. Robert W. Fogel et. al., "The Economics of Mortality in North America, 1650-1910: A Description of a Research Project," Historical Methods, 11 (Spring, 1978), p. 75-108.

42. See the life expectancy figures in Richard Easterlin, "The American Population," in American Economic Growth, Lance Davis et al., New York, 1972. In an unpublished and untitled paper (1980), Roderick Floud has argued that one should investigate the age at which final height is achieved, as well as the level of final height, before drawing any inferences about the relative or absolute state of a population's nutrition. Study of this feature of the height-by-age profile, with our data, is complicated by misreporting of age. Yet, we have made some estimates, and they tend to support the view that Revolutionary Americans were rather well nourished. Floud observes that "growth in stature virtually ceases (in the sense that only some 2% is added) for boys in present-day North America and North-West Europe at 17.5 [years] and for girls at 15.5." Based on the information contained in the French and Indian and Revolutionary War muster rolls, we calculate that the native born males achieved 98% of their final height between ages 18.0 and 18.7. Given that, as noted above, there have been significant increases in final height since World War II, we suggest that, in this case, the implications of this piece of information are not inconsistent with those of the estimated final heights.