9-1982

Height, Weight, and Fertility Among Participants of the Third Harvard Growth Study

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Scott, Eugenie C., ***Height, Weight and Fertility Among the Participants of the Third Harvard Growth Study***, Human Biology, 54:3 (1982:Sept.) p.501

Height, Weight and Fertility Among the Participants of the Third Harvard Growth Study

By Eugenie C. Scott[1] and Carl Jay Bajema[2]

ABSTRACT

The relationship between weight, height, weight/height² and fertility is examined in 610 females and 621 males from a 1968 follow-up study of the Third Harvard Growth Study participants. These subjects were born between 1912 and 1918 in the USA. Their physical and mental growth were studied for up to 12 years while they attended public schools in the Boston, Massachusetts, area. Height is not significantly related to fertility in either females or males, but weight and weight/height² is positively related to fertility in females ($r = +.117$ and $+.100$ respectively) and weight/height² is positively related to fertility in males ($r = +.09$). Weight and weight/height² at skeletal age 12 of 305 females are both negatively correlated with later fertility ($r = -.102$ and $-.141$ respectively). Thus girls who later had large families were not heavier than average, but in fact, were taller and slimmer. In these data it appears the differential reproduction for heaviness is not likely to have had genetic effects but is probably a secular trend. The fact that taller and slimmer girls later went on to have larger families may be significant for the consideration of sexual selection.

The relationship between physique and fertility is of interest in evolutionary studies. Evolution is produced by differential reproduction whether brought about by adaptive processes (produced by natural and sexual selection) or random processes (produced by genetic drift). Differential reproduction can be documented in a relatively straight-forward fashion; demonstrating whether the differential reproduction is adaptive or not is less easy. Nonetheless, the documentation of differential reproduction of individuals with different physical characteristics is of interest and may be evidence for either evolution or a (nongenetic) secular trend.

In the present study, the relationship between height, weight, and weight/height² in the sample from the Third Harvard Growth Study is analyzed. People who had been studied as children were followed up in adulthood and fertility and physique data were collected from them. At the time of the follow-up study, however, most of the childhood data on the participants were not available for analysis. We report here the follow-up data for both sexes plus some of the childhood data for many of the females.

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Human Biology, September, 1982, Vol. 54 No. 3, pp. 501-516.

MATERIALS AND METHODS

The object of the Third Harvard Growth Study was to measure longitudinally the physical and intellectual growth of normal children. The project was begin in 1922 by Walter F. Dearborn and colleagues, who studied all children in three Boston area school districts from the time they entered school in the first grade until they either graduated, moved, or dropped out of school. Many anthropometric measurements and intelligence tests were taken on these children through the years (Dearborn et al. 1938). The number of students with 11 or more complete years of measurement was 1225. Partial data is available on other children, making a total of approximately 4000.

In 1968, one of us (CJB) conducted a followup study on 1533 individuals, most of whom were then approximately 50-55 years old. Data were collected via a mailed questionnaire and through examining vital statistics and reunion records for those either deceased or not responding to the questionnaire.

Weight, height and fertility were self reported by informants during the 1968 follow-up, and are also available for many of them as children. Weight/height^2 was chosen as a measure of "fatness", "stoutness", or "obesity" because it is "highly correlated with weight and consistently independent of height" (Khosla and Lowe, 1967, p. 128).

Self-reported height and weight tend to be biased measurements. Both men and women tend to report themselves as slightly taller and slightly lighter than they actually are (Clauser et al. 1972; Bouchalova et al. 1976). However, the correlation between reported and actual weight is very high, ranging from .90 to .97 (Clauser et al. 1972; Bouchalova et al. 1976). The goal of this research is to look at the relationship *between* physique and fertility, not at size *per se*. Therefore the data is not biased for our purposes.

Weight in childhood was measured in kilograms to the nearest hectogram, and height was measured in millimeters. In the follow-up study, weight was self reported in pounds and later converted to kilograms; height was reported in feet and inches and later converted to millimeters. Fertility was recorded as total number of offspring per individual, and includes offspring who died in infancy.

Data were analyzed separately for males and females. We plotted the variables to check for outliers. Only a few cases of very high fertility were judged outlying, and were removed (3 males, 5 females). We further subdivided the data into reproducing and nonreproducing subsets to see if there were any differences in physique between these classes.

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Next we utilized linear regression to examine the data for linear relationships between the physique variables and fertility. Linear relationships could indicate directional selection. Then we examined the data for curvilinear relationships between physique and fertility using two methods: polynomial regression (fertility $= a + bVar + bVar^2$) (Vetta, 1975) and regressions of fertility on transformed physique variables. One transformation was the difference between the absolute value of each measurement and the mean (Mitton, 1975). The quadratic equation expresses a parabola. In the transformation, large values would represent cases at the extremes, and small values would reflect cases close to the mean of the distribution. Significant positive correlations would imply curvilinear relationships ("U" shaped) between the dependent and independent variables. This could indicate diversifying selection. Significant negative correlations would imply another kind of curvilinear relationship ("n" shaped) showing that individuals closer to the mean for the physique variables were those with the highest fertility. This distribution implies stabilizing selection.

There is another nonlinear relationship which can be tested for. Tall or heavy individuals may be associated with fertility differently than short or light ones. We therefore looked at the regression of fertility on subsets of the physique variables: those cases above the mean for the variable and those below the mean.

We also used multiple regression to consider simultaneously the three main variables plus the transformed variables (Vetta, 1975).

Since social and cultural factors have been shown in previous studies to relate to physique and fertility, we also examined ethnicity and income as factors. Ethnicity was self-reported by the participants in 1968, in the following categories: North European, Italian, Southern European, Negro, Jewish, Mixed Stock, and Unknown. These categories are the same as those used in the original 1920's study. Income, as self reported in the 1968 follow-up survey, was listed in six categories, ranging from "less than \$3000" to "over \$12000." We analyzed the data for physique and fertility using partial correlation, controlling for ethnicity, and in another analysis, controlling for income.

Because data were available on many of the females as school age children as well as when adults, we could look at how size and physique of a woman in youth might associate with later fertility. Data presented in Dearborn, et al. (1938) includes heights, weights and skeletal ages determined by wrist X-rays, as detailed by Shuttleworth, (1938). We chose the heights and weights at skeletal ages between 138 and 150 months (age 12 ± 6 months). There were 305 females with data available within this age

Table 1

Means, N of Samples, and Standard Deviations for Male and Female Subsets

	Total Fertility N	Total Fertility $\bar{X}$	Total Fertility SD
all males	782	2.146	1.665
all females	743	2.047	1.644

	Height in 1968			Weight in 1968			Weight/Height^2		
	N	$\bar{X}$	SD	N	$\bar{X}$	SD	N	$\bar{X}$	SD
all males	621	1767.211	65.677	607	799.008	108.485	606	2.561	.300
reproducing males	513	1766.437	63.282*	503	800.789	107.799	502	2.568	.297
non-reproducing males	108	1770.889	76.257*	104	790.394	111.877	104	2.527	.316
all females	610	1622.638	57.913	600	644.018	110.856	600	2.447	.400
reproducing females	487	1623.807†	57.057	478	648.814†	108.258	478	2.461	.389*
non-reproducing females	123	1618.008†	61.211	122	625.230†	119.112	122	2.390	.437*

Statistics calculated on comparison between reproducing and non-reproducing subsamples.
*Significant at <.05 level by F test for equality of variances
†Significant at <.05 level by t test

range and in adulthood. We analyzed these data in the same way adult height, weight, weight/height^2 and fertility were examined: through the regression of fertility on the three physique variables. SPSS (Nie, et al. 1975) was used for all statistical analyses.

Results

Analysis of Male Data

Table 1 compares the means and variances of the three physique variables height, weight, and weight/height^2 for both the male and the female subsamples. Males who reproduced were somewhat shorter and heavier than nonreproducing males, but the means for height and weight were not significantly different. Nonreproducing males were, however, significantly more variable in height, though no significant differences in the variance of weight or weight/height^2 were shown.

The correlations and F ratios of the linear regression of fertility on the physique variables are presented in Table 2.

In males, only weight/height^2 was significantly related to fertility. Weight and height were not. Absolute difference from the means of weight, height, or weight/height^2 were not significantly related to fertility. When fertility was regressed on cases above the mean for weight, height and weight/height^2, and separately on those below these means, no significant relationships were found. One can also examine nonlinear relationships by regressing the dependent variable on exponential values of the independent variable. Table 3 presents regressions of fertility on height and the square of height, and on weight and the square of weight. No statistically significant curvilinear relationships were found between physique and fertility in males, (r ranged from +.05 to +.07.)

Since all the physique variables are correlated, a stepwise multiple regression of fertility on weight, height and weight/height^2 was run. The variable with the highest correlation, weight/height^2, was entered first. When height was added, the r increased only slightly and the F ratio decreased (Table 4). With all three variables in the equation, the multiple r increased only about .01, and the F ratio continued to decrease. No improvement in prediction was gained by using all three variables.

Because cultural, social, and ethnic variables also influence fertility, we measured the effect of variations in ethnicity and income on the relationship between weight and fertility. Weight and fertility might be associated only with particular large ethnic groups in the sample, biasing

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Table 2

Correlation of Fertility with Physique Variables

	Males				Females			
	N	r	r^2	F	N	r	r^2	F
Height	606	.042	.002	1.048	600	.009	.000	.044
Weight	606	.052	.003	1.658	600	.104	.011	6.477*
WT/HT^2	606	.086	.007	4.472*	600	.100	.010	5.994*
$\bar{X}_{HT}$-HT	606	.070	.005	3.012	610	.050	.002	1.494
$\bar{X}_{HT\text{-}WT}$	606	.028	.001	.467	600	.038	.001	.850
$\bar{X}_{WT/HT}2\text{-}WT/HT^2$	606	.015	.000	.127	600	.021	.000	.268
$\bar{X}_{WT}$-HT (GT)[a]	324	.037	.001	.447	333	.056	.003	1.040
$\bar{X}_{HT}$-HT (LT)[b]	297	.105	.011	3.306	277	.032	.001	.286
$\bar{X}_{WT}$-WT (GT)[a]	286	.089	.008	2.288	255	.107	.011	2.905
$\bar{X}_{WT}$-WT (LT)[b]	321	.030	.001	.280	345	.086	.007	2.533

[a]GT: Variable difference from the mean greater than zero
[b]LT: Variable difference from the mean less than zero
*Significant at .05 level (2-tailed test)

Table 3

Unstandardized Regression Coefficients, r and F for Fertility Regressed on Physique Variables

	Intercept	Variable	Variable²	r	F
Males (N = 606)					
Fertility =	4.05	−.101 Ht		.04	1.048
		†	†		
Fertility =	1.665	+.762 Wt		.05	1.658
	1.970	+.579 Wt	+.460 Wt²	.05	.838
Females (N = 600)					
Fertility =	1.829	+.241 Ht		.009	.044
		†	†		
Fertility =	1.124	+.153 Wt		.104	6.477*
	1.095	+.194 Wt	−.298 Wt²	.104	3.238

*< .05 (2-tailed test)

†Height and Height² not reported because of insufficient tolerance

Table 4

Stepwise Multiple Regressions of Physique Variables. Unstandardized Regression Coefficients, r and F

	Intercept	Wt/Ht^2	Height	Weight	r	F
Male Fertility =	1.121	+.450			.086	4.472*
	2.755	+.441	−.912		.094	2.668
	8.93	−.766	−.442	+.388	.095	1.835
		Weight	Height	Wt/Ht^2	r	F
Female Fertility =	1.237	.153			.104	6.477*
	2.386	.165	−.758		.107	3.432
	20.013	−3.152	−.116	−3.605	.125	3.164

*p = .05 (1-tailed test)
**p = .01 (1-tailed test)

Table 5

Ethnicity and Income in the 1968 Harvard Growth Study Follow-Up

	Males	Females
ETHNICITY		
1. No. Europe	539	519
2. Italian	146	136
3. So. Europe	20	16
4. Negro	7	3
5. Jewish	41	51
6. Mixed	9	6
7. Unknown	20	12
INCOME		
1. Not Working	32	364
2. Less than $3,000	5	58
3. $3,000–$4,999	20	105
4. $5,000–$6,999	64	82
5. $7,000–$8,999	139	22
6. $9,000–$11,999	142	16
7. $12,000 and over	212	7
8. No information	168	89

conclusions based on the sample as a whole. Similarly, income has been shown to influence both weight and fertility. The income and ethnicity distributions are shown in Table 5. We ran partial correlations of fertility and the physique variables, holding these other factors constant. Table 6 shows that the correlations between the physique variables and fertility in the male subsample remained essentially unaltered when ethnicity or income are held constant.

Analysis of Female Data

Table 1 compares the means and variances for the three physique variables height, weight, and weight/height^2 for reproducing and nonreproducing females. Reproducing females are significantly taller and heavier than nonreproducing women. Nonreproducing females are significantly more variable than reproducing females in weight/height^2.

Table 2 presents product moment correlations of fertility with physique variables. Height is unrelated to fertility, but weight and weight/height^2 are significantly related.

As was the case with the male data, the transformed weight and height variables did not show significant relationships with fertility (Table 2). The

Table 6

Partial Correlations of Fertility on Weight, Height and Weight/Height² Controlling for Ethnicity and Income

	Zero Order Partials Fertility × Physique Variable			*1st Order Partials* Fertility × Physique Variable, Controlling for *Income*			*1st Order Partials* Fertility × Physique Variable, Controlling for *Ethnicity*		
				Male Sample					
	r	*Sig.*	*N*	*r*	*Sig.*	*N*	*r*	*Sig.*	*N*
Weight	.048	.130	561	.039	.179	560	.047	.131	560
Height	−.058	.083	561	−.067	.057	560	−.058	.084	560
Wt/Ht^2	.091	.016	561	.086	.020	560	.092	.015	560
				Female Sample					
Weight	.123	.002	556	.118	.003	555	.123	.002	555
Height	.019	.329	556	.036	.200	555	.013	.380	555
Wt/Ht^2	.117	.003	556	.104	.007	555	.119	.003	555

other analysis performed to test for nonlinear relationships, the quadratic regression of fertility on a physique variable, proved nonsignificant for both height and weight (Table 3). The correlation of weight and weight^2 with fertility was +.10, the same as when weight alone was regressed with fertility, and the F ratio decreased. No improvement in prediction is gained, therefore, by using a polynomial regression instead of a simple regression. Results of stepwise multiple regression of fertility on the three physique variables is presented in Table 4. Weight/height^2 is the best predictor, and little improvement is gained by adding height. When all three variables are in the equation, the r rises .02 points but the F ratio decreases, though not below the .05 level of significance. We conclude that the relationship between weight and fertility (also expressed in weight/height^2) is linear and positive.

To see if the association between fertility and weight were explainable as due to either ethnic or income variables, we ran partial correlations of fertility and physique holding income and ethnicity constant. Table 6 shows little or no change when these social variables are held constant.

The tendency for heavy and heavy-for-height females to have large families holds across ethnic and income groups, and is therefore not just a result of ethnicity or income. Since the weights used in this analysis are adult (postreproductive) (1968) weights, the causal relationship between weight and fertility is not clear. Did women who had large families become heavy as a result of having had several children, or were they heavy before their pregnancies? It has been suggested that heavier women have a reproductive advantage over lean ones but it is also the case that multiparous women have a tendency for weight gain. Fortunately, our data lend themselves to an explanation. Having the weights of 305 of these women at skeletal age 12 years, ± 6 months, we first examined these data for outliers (none were found). We checked to see if this subsample was biased by comparing the mean and standard deviation of the 1968 fertility, height, weight, and weight/height^2 of these women with the fertility, height, weight, and weight/height^2 of all the women in the sample. The subsample did not significantly differ from the total sample in the means of weight, height, fertility, or weight/height^2. The total sample was more variable in weight and less variable in weight/height^2 than the subsample (Table 7). We also looked at the weight, height and weight/height^2 of the subsample in adulthood, and found the correlation of these variables with fertility to be somewhat lower than physique variable correlations from the entire female sample. They showed the same "shape", however: height had the lowest correlation with fertility, and weight and weight/height^2 were more strongly related (Table 8).

Table 7

Comparisons of Fertility and Physique Variables of Total Female Sample and Skeletal Age 12 Subsample

	Weight in 1968			Height in 1968		
	N	$\bar{X}$	SD	N	$\bar{X}$	SD
Total Sample	600	644.018	110.856	610	1622.638	57.913
Sub Sample	308	640.750	101.511	314	1622.041	59.889
	Weight/Height² in 1968			Fertility in 1968		
Total Sample	600	2.447	.400*	600	2.220	1.634
Sub Sample	308	2.435	.365*	305	2.143	1.703

*p < .05 by F test

Table 8 presents results of regressions of adult fertility on the weight, height, and weight/height² of the child at skeletal age 12. The relationship between youth physique and later fertility differs from that between adult physique and fertility. In young girls, the highest physique and fertility correlation is with weight/height²—but the relationship is negative ($r = -.14$). Weight also has a negative correlation with fertility ($r = -.10$). Stature, of no significance to fertility in this group at age 50-55, is positively correlated, but not at a high level ($r = +.05$). Table 9 presents the results of a stepwise multiple regression of fertility on weight at 12, height at 12, and weight/height² at 12. Not much improvement in the multiple r

Table 8

Fertility Regressed on Physique Variables Female Skeletal Age 12 Sample, N = 305

Variable	r	r²	F
Weight (age 12)	−.102	.010	3.169
Height (age 12)	.049	.002	.744
WT/HT² (age 12)	−.141	.019	6.144*
Weight (1968)	.087	.008	2.302
Height (1968)	.015	.000	.072
WT/HT² (1968)	.076	.006	1.755

*Significant at <.01

Table 9

Female, Skeletal Age 12 Subsample. Stepwise Multiple Regressions of Fertility on Physique Variables. Unstandardized Regression Coefficients, r and F

Intercept	WT/HT² (at 12)	Height (at 12)	Weight (at 12)	r	F
3.784	−.908			.14	6.144*
2.355	−.887	.953		.15	3.276
−11.671	2.875	.107	−.182	.16	2.672

*p < .05

is gained after entering height and weight; weight/height² continues to be the best predictor of fertility. However, since the correlation between the variables is negative, the analysis illustrates that the more *slender* girls (rather than the heavy for height girls) went on later to have higher fertility.

From these results we may tentatively conclude that women who in adulthood had larger families became heavier than the sample average during adulthood. This may or may not have been related to the bearing of larger than average families. These women were not heavy or heavier for height at skeletal age 12. In fact, there is a tendency for taller and slimmer girls to produce larger families in later life.

Discussion

Studies of physique and fertility differ considerably in their conclusions. Some studies show differential reproduction for stature (Conterio and Cavalli-Sforza, 1960; Damon and Thomas, 1967; Vetta, 1975; Mitton, 1975) and others do not (Lasker and Thomas, 1976; Bailey and Garn, 1979; Mueller et al. 1981). Body build also is not uniformly reported as positively or negatively associated with fertility (Bailey and Garn, 1979).

Possible reasons for these discrepancies are numerous. Socioeconomic status, ethnicity, and other factors vary from sample to sample, influencing fertility as well as individual and societal expectations of proper size and shape. Research methodologies of the investigators differ as well.

Socioeconomic status varies in its relationship to physique and fertility. Garn et al. (1980) conclude that in western societies, fatness, fertility and lower socioeconomic status are all positively associated, whereas in many developing countries, fatness and fertility are associated only in the upper socioeconomic classes.

The role of ethnicity is unclear. Data from Harvard University graduates, an ethnically and socioeconomically homogeneous sample, and data from Ann Arbor, Michigan, an ethnically and socioeconomically heterogeneous sample, both show the same type of stabilizing selection in some analyses (Vetta, 1975; Mitton, 1975).

Different techniques of analysis are needed if the sample consists of young individuals, compared to samples consisting of those past reproductive age. In addition, the relationship between fertility and physique may be either linear or nonlinear. The data should be examined for nonlinear relationships (Welch, 1970; Vetta, 1975; Mitton, 1975), although a nonlinear analysis does not always explain the greatest amount of variance (Bailey and Garn, 1979). Damon and Thomas (1967) discovered no relationship between weight or ponderal index and fertility, and a slight positive relationship between stature and fertility in the group which they studied. Vetta (1975) reanalyzed their data and showed a curvilinear relationship between both weight and fertility, and height and fertility, suggesting stabilizing selection for these traits. Mitton (1975) also reanalyzed these data but with a different technique, concluding stabilizing selection for height was taking place, but weight was not involved in differential reproduction. We therefore applied both linear and nonlinear analysis procedures to our data.

As do many other studies of physique and fertility, (Clark and Spuhler, 1959; Mueller, 1979) this followup study on the Third Harvard Growth Study participants shows a positive association between some physique variables and fertility. The correlations are low and only small percentages of the variance in fertility are being explained by physique.

Bailey and Garn (1979) discuss secular trends in fatness since in their sample genetic factors appeared to explain less variance than socioeconomic status (measured by income). In our sample, however, the relationships found between fatness and fertility were unchanged even when ethnicity and income were held constant. Relative weight in adulthood is positively associated with fertility in both males and females, but weight at age 12 among females is not. It seems as if the adult female weight and fertility association towards the end of the childbearing years is a result of environmental factors. Women who produced large families tend to gain relatively more weight in adulthood than women who produced smaller families or who did not reproduce. Women who produced large families were not heavier at age 12 than lower fertility women. This suggests that a secular trend is operating, but not one associated with income as found in Bailey and Garn (1979).

The fact that taller and slimmer 12-year-old girls ended up having larger families is interesting from the standpoint of possible sexual selection, but we cannot discuss this issue here.

In summary, the analysis of weight, height, weight/height^2 and fertility among the Third Harvard Growth Study participants showed no significant relationship between fertility and height, but did show low significant positive relationships with weight and weight/height^2. These results may be due to environmental factors in the female sample, since heaviness in childhood is negatively associated with later fertility. These environmental factors, however, do not relate to ethnicity or income, but to some other as yet unanalyzed factors. Further follow-up studies on this sample may elucidate these variables.

Received: 1 December 1980.
Revision received: 14 October 1981.

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