Fitness, BMI and Academic Achievement

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Abstract: Studies have separately shown that obesity and physical fitness are associated with academic achievements. However, most studies do not take into account the combined effect of obesity and physical fitness on academic achievements. In this paper, we investigate the collective effect of obesity and physical fitness on academic achievements. The partial relationship between obesity, as measured by Body Mass Index (BMI), and academic achievements was non-linear. In addition, BMI appears to be confounded with physical fitness, and this suggests that schools could focus on a fitness programme rather than on merely a dietary programme to help raise student academic achievement.
Keywords: BMI, Physical Fitness, Academic Achievement.

Background

Numerous studies have shown that obesity is associated with poor academic performance (e.g. Taras and Potts-Datema, 2005). Some studies have also shown that students who score higher in physical fitness tests tend to perform better academically than students who scored lower (e.g. Girssom, J. B., 2005). However, many of these studies did not take into account the combined effect of obesity and physical fitness on academic performance. This paper aims to address their collective effect on academic achievement.

Research Methods

In this study, 41,290 12-year old students were included in the analytic sample. These students constitute about 80% of the Primary 6 students who sat for the Primary School Leaving Examination (a national examination) in 2004. The Achievement score (ACHIEVEMENT) of the students was computed based on their performance in each of the examinable subjects offered at Primary 6, and used as the outcome variable in this study.

The height, weight and demographic background of the students such as parents' educational qualifications and residential type were collected. The Body Mass Index (BMI) of the students was computed by dividing the mass (in kilograms) by the square of the height (in metres), and used as a continuous explanatory variable in this study. The Fitness score (FITNESS) of the students was computed based on their performance at the National Physical Fitness Assessment, which comprises six events: one minute sit-ups, sit and reach, standing broad jump, 4 x 10 metres shuttle run, 30 seconds pull-ups (or inclined pull-ups for girls), and 2.4 km run-walk. To control for the Socio-Economic Status (SES) of the students, a composite SES index was derived from the residential type of the students and their parents' educational qualifications, to reflect the SES of the students.

Description of Variables

[1] This paper was supported by funds from the Ministry of Education, Singapore. The paper does not necessarily represent the official positions of the Ministry of Education, Singapore. The contents are the sole responsibility of the authors.

For ease of interpretation, all continuous variables were standardised to a mean of 0 and a standard deviation of 1. The descriptive statistics and distribution for the BMI of the 41,290 students are provided in Table 1 and Figure 1.

Table 1: *Descriptive Statistics of BMI*

N	Minimum	Mean	Maximum	SD
41290	7.40	18.66	55.78	3.67

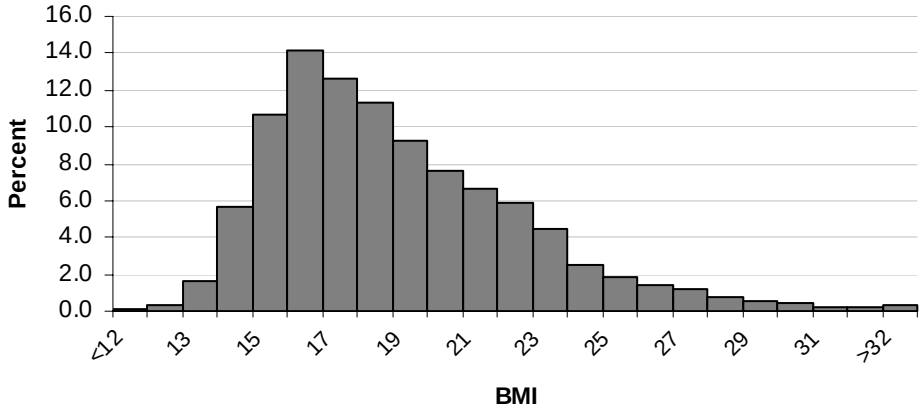

Figure 1: *Distribution of BMI*

The Pearson correlation coefficients of the variables are shown in Table 2. The correlation between FITNESS and BMI was moderately high at -0.426. This agrees with the conventional observation that fitness usually decreases with increase in BMI. On the other hand, the correlation between FITNESS and ACHIEVEMENT was moderately small (0.193), while the correlation between BMI and ACHIEVEMENT was low (-0.075) but nonetheless statistically significant (likely because of the large sample size). The correlation between FITNESS and ACHIEVEMENT (0.193) shows that higher fitness level is associated with better academic achievements, even though the effect is not large.

Table 2: *Pearson Correlation Coefficients of Variables*

	ACHIEVEMENT	BMI	FITNESS	SES
ACHIEVEMENT	1.000	-0.075	0.193	0.450
BMI	-0.075	1.000	-0.426	-0.028
FITNESS	0.193	-0.426	1.000	0.119
SES	0.450	-0.028	0.119	1.000

Body Mass Index

The bubble plot[2] of mean ACHIEVEMENT against BMI (Figure 2) suggests that the relationship between BMI and ACHIEVEMENT is not linear. Indeed, this should be expected as students with very low or very high BMI are likely to be disadvantaged since overweight students could have issues with self-esteem or have obesity-related health problems, while underweight students could be suffering the effects of undernourishment. To reflect this, a quadratic term for the BMI variable should be added to the statistical model to account for its non-linear effect.

[2] The size of each bubble represents the number of students with the particular integer BMI value.

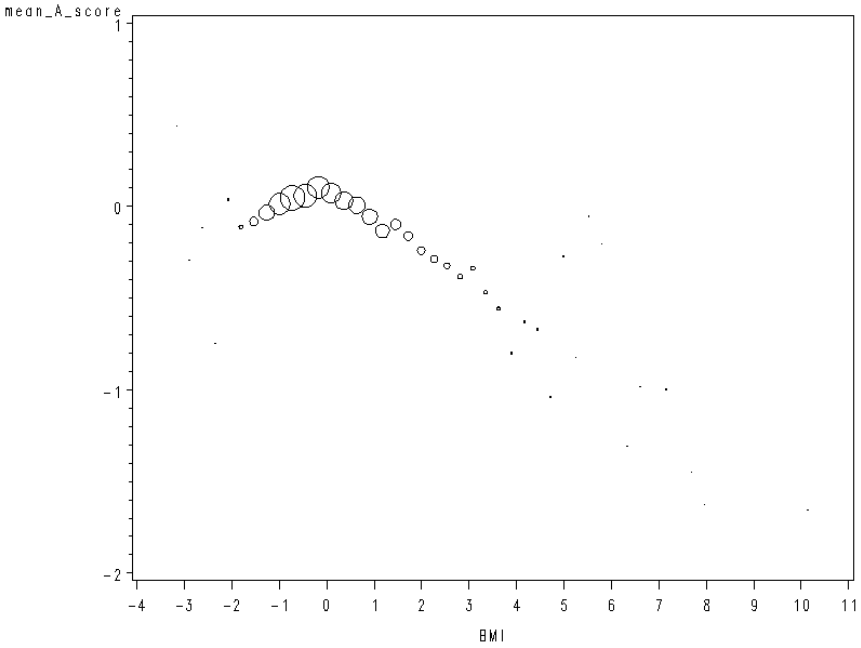

Figure 2: *Bubble Plot of Mean Achievement against BMI (rounded to nearest integer)*

The scatter plot of ACHIEVEMENT against BMI (Figure 3) showed that there is much variation in ACHIEVEMENT scores for students with the same BMI score. This accounts for the low correlation between the two variables (-0.075).

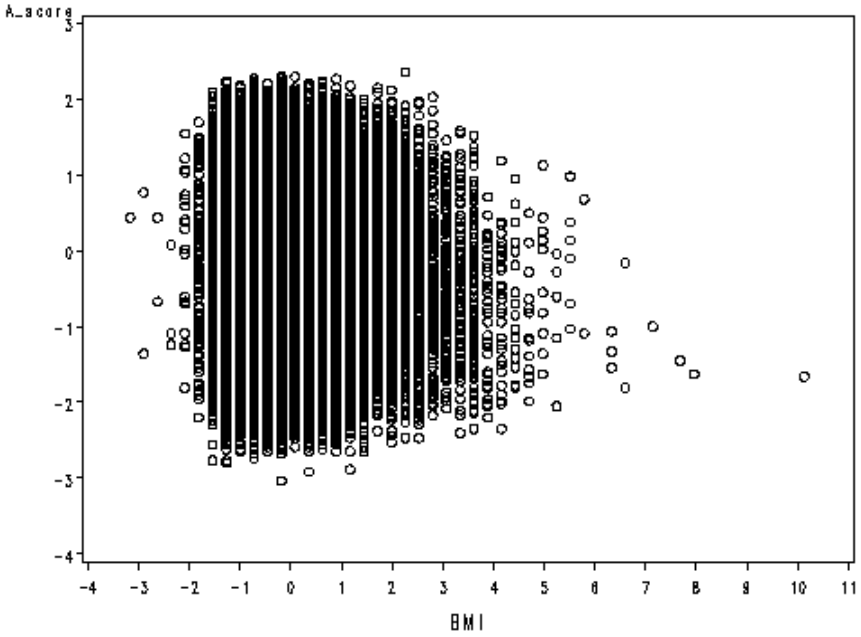

Figure 3: *Scatter Plot of ACHIEVEMENT against BMI (rounded to nearest integer)*

Physical Fitness

The bubble plot[3] of mean ACHIEVEMENT against FITNESS (Figure 4) showed that the relationship between ACHIEVEMENT and FITNESS was approximately linear. However, the scatter plot of ACHIEVEMENT against FITNESS (Figure 5) showed that there is much variation in ACHIEVEMENT for students with the same FITNESS score. This accounts for the moderately small correlation between the two variables (0.193).

[3] The size of each bubble represents the number of students with the particular FITNESS score.

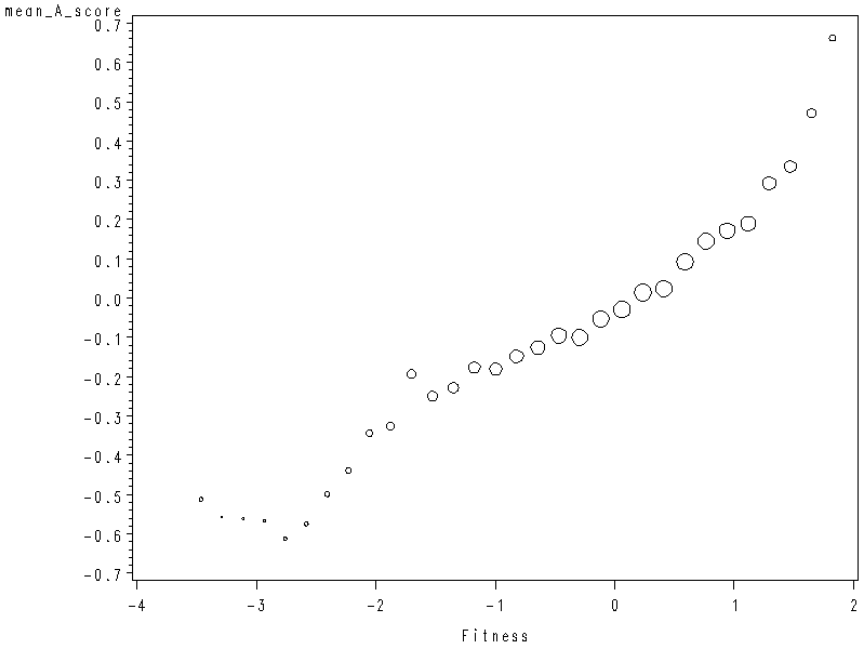

Figure 4: *Bubble Plot of Mean ACHIEVEMENT against FITNESS*

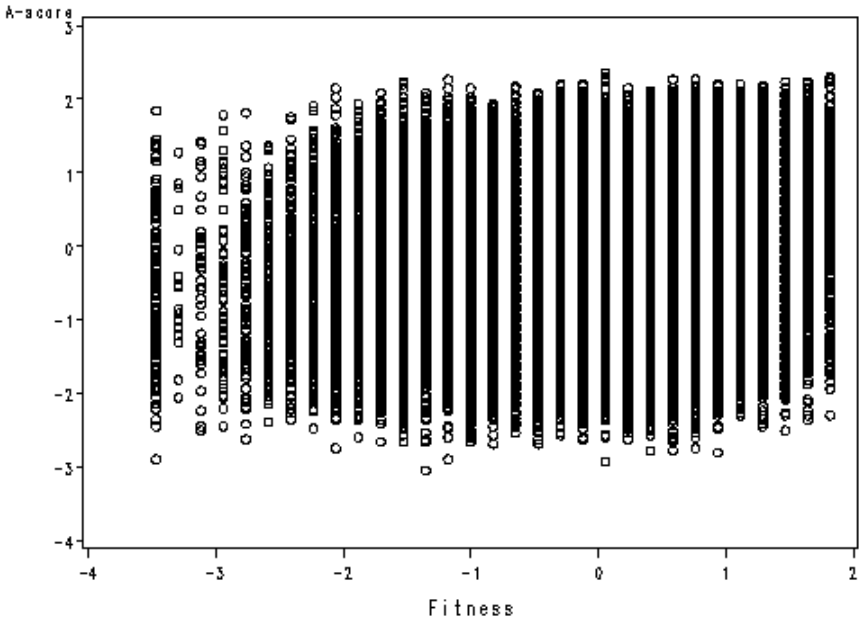

Figure 5: *Scatter Plot of ACHIEVEMENT against FITNESS*

Results and Discussions:

Model 1 – BMI Only. Our first analysis considered a simple OLS regression model (Equation 1) with ACHIEVEMENT as the outcome and BMI as the only predicting variable. As expected, the effect of BMI on ACHIEVEMENT is weak but statistically significant (see Table 3).

$$\text{ACHIEVEMENT} = \beta_{10} + \beta_{11}\,\text{BMI} \qquad (1)$$

Model 2 – BMI and BMI^2. We next include both BMI and BMI^2 as input variables in Model 2 (Equation 2). Statistically, Model 2 is significantly better than the model with only BMI as the independent variable. This is evident from the increment in R^2 (see Table 3).

$$\text{ACHIEVEMENT} = \beta_{20} + \beta_{21}\,\text{BMI} + \beta_{22}\,\text{BMI}^2 \qquad (2)$$

Model 3 – FITNESS only. OLS regression analysis showed that FITNESS alone could account for about 3.7% of the total variation in ACHIEVEMENT, which is larger than the proportion (1.0%) explained by both BMI and BMI^2 (see Table 3).

$$\text{ACHIEVEMENT} = \beta_{30} + \beta_{31}\,\text{FITNESS} \qquad (3)$$

Model 4 - Full Model. Since we expected SES, FITNESS and BMI to be correlated with ACHIEVEMENT, and are themselves pairwise correlated (both empirically and based on theory), we have included all these variables in our final model to account for any confounding effects between SES, FITNESS and BMI.

$$\text{ACHIEVEMENT} = \beta_{40} + \beta_{41}\,\text{BMI} + \beta_{42}\,\text{BMI}^2 + \beta_{43}\,\text{FITNESS} + \beta_{44}\,\text{SES} \qquad (4)$$

OLS regression of ACHIEVEMENT on SES, FITNESS, BMI and BMI^2 gave a model that explained about 22% of the variation in ACHIEVEMENT (see Table 3). The Type I and Type II SS showed that both BMI and BMI^2 should be included in the model to reflect more completely the effect of BMI on ACHIEVEMENT (full ANOVA tables are given in Appendix).

Table 3: *Comparison of Alternative Models*

	Model 1	**Model 2**	**Model 3**	**Model 4**
Intercept	0.000	0.000	0.000	0.000
BMI	-0.075 **	0.346 **		0.229 **
BMI^2		-0.426 **		-0.237 **
FITNESS			0.193 **	0.136 **
SES				0.432 **
R^2	0.006 **	0.010 **	0.037 **	0.223 **

** $p < 0.05$, ** $p < 0.01$*

Model 4 suggests that after the effect of SES was controlled for, FITNESS had a larger partial (unique) effect on ACHIEVEMENT than BMI and BMI^2. All else being equal, a standard deviation change in FITNESS would see a 0.14 standard deviation change in ACHIEVEMENT.

Both standardized BMI and BMI^2 have statistically significant partial (unique) effects on ACHIEVEMENT. Figure 5 shows the partial effect of BMI on ACHIEVEMENT, when holding SES and FITNESS constant at their mean values. The range of standardised BMI scores indicated in the chart (-1.5 to 3.1) represents the 1st to 99th BMI percentile. ACHIEVEMENT reaches a maximum when BMI is about 0.5 (when holding SES and FITNESS constant). This is expected as students who are at the extreme ends of the BMI spectrum may have health problems or self-esteem issues, and hence are less likely to perform well academically.

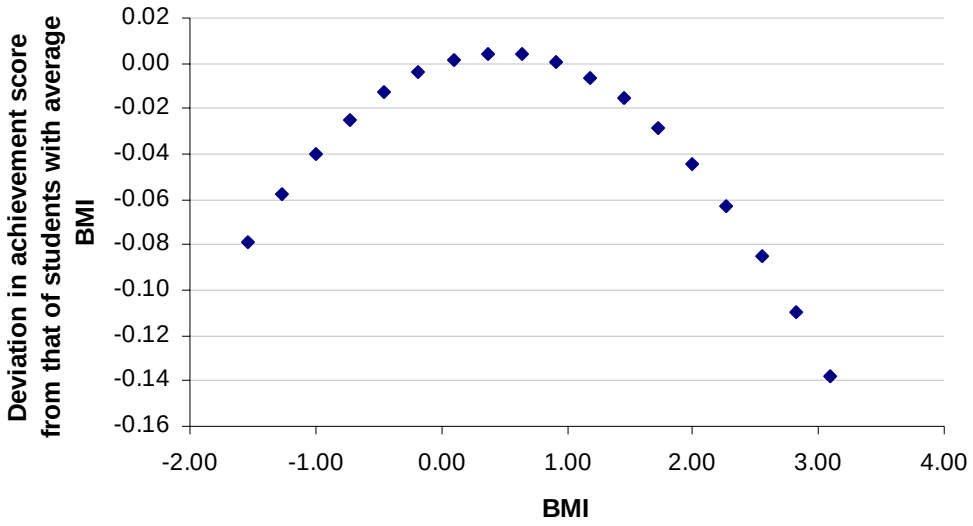

Figure 5: *Partial Effect of BMI on ACHIEVEMENT*
(Holding SES and FITNESS Constant at their Mean Values)

Based on the 'central' 98% of students in the sample (in terms of BMI), the difference in ACHIEVEMENT due to the partial effect of BMI is not more than 0.14 standard deviation of ACHIEVEMENT. The reason for the small partial effect of BMI (when holding FITNESS and SES constant) could be that the effect of obesity on academic achievement operates through physical fitness.

To study this, an OLS regression model comprising only SES, BMI and BMI^2 was generated:

Predicted ACHIEVEMENT = 0.446 SES + 0.24058 BMI - 0.30647 BMI^2

Figure 6 shows the partial effect of BMI on ACHIEVEMENT in this reduced model. As before, the range of standardised BMI scores indicated in the chart (-1.5 to 3.1) represents the 1st to 99th BMI percentile. Based on this range, we see that the difference in ACHIEVEMENT due to the partial effect of BMI is 0.36 standard deviation of ACHIEVEMENT. Hence, the partial effect of BMI on ACHIEVEMENT is considerably greater when FITNESS is not controlled for. The reduction in the partial effect of BMI on ACHIEVEMENT when we hold FITNESS constant suggests that the effect of the BMI variables on ACHIEVEMENT operates largely through FITNESS.

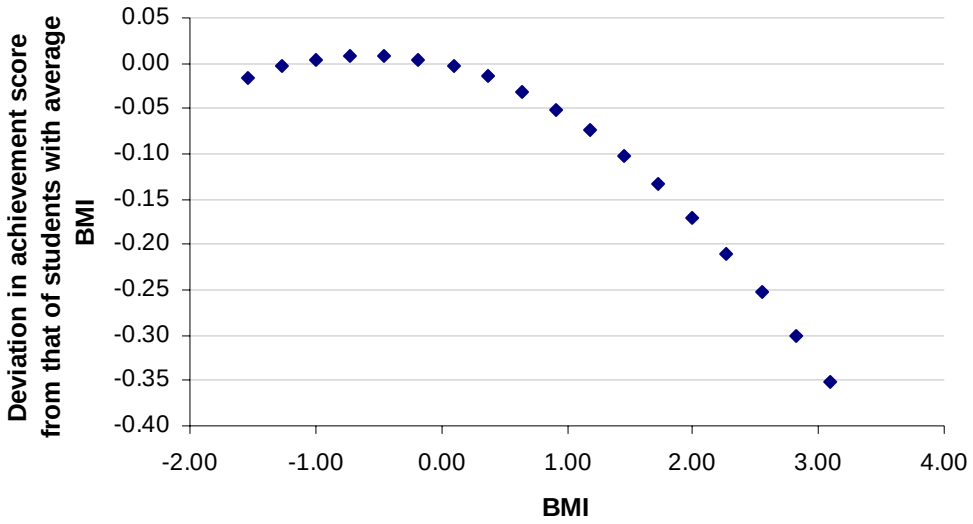

Figure 6: *Partial Effect of BMI on ACHIEVEMENT*
(Only Holding SES Constant at its Mean Value)

Conclusions

The effects of Fitness and BMI on academic achievement were statistically significant even after taking into account the differences in SES. However, the effects are small. Fitness score on its own explained only about 3.7% of the variation in the achievement score. Our analysis also shows that the relationship between BMI and academic achievement was not linear. This is not unexpected because a very high or very low BMI indicates a departure from ideal physical size as well as physical wellbeing. Furthermore, our analysis shows that BMI (and BMI^2) is not a good predictor of academic achievement, after the Fitness score of students have been taken into account. We therefore suspect that the effect of obesity on academic achievement score operates largely through physical fitness.

While what is presented in this paper appears to diverge from studies which traditionally assert a high association between obesity and academic achievement, this is likely because these studies do not take into account the effect of the confounding physical fitness variable. In addition, those studies were generally more specific and focused on the effect of being obese on academic achievement. Most of them also did not use BMI as a continuous explanatory variable. We would like to emphasise that BMI is not a perfect indicator of obesity, as BMI does not distinguish between muscle mass and fat mass, nor take into account bone density.

Finally, it is important to note that the analyses we have conducted do not allow us to establish if the relationships between physical fitness and academic achievement, and that between BMI and academic achievement are causal. Nonetheless, the findings in this study could inform the design of physical education and physical health programmes. Instead of focusing too much on reducing or controlling the body weight of obese children through dietary programmes, attention should also be given to activities that enhance their physical fitness. Only such a two-pronged approach is likely to raise the school children's overall academic achievement optimally.

References

Girssom, J. B. (2005). Physical Fitness and Academic Achievement. *Journal of Exercise Physiology Online Vol. 8, No 1.*

Taras, H., and Potts-Datema, W. (2005). Obesity and Student Performance at School. *Journal of School Health Vol. 75, No. 8.*

Appendix

Model 1

Analysis of Variance					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	1	231.41485	231.41485	232.71	<.0001
Error	41288	41058	0.99442		
Corrected Total	41289	41289			

Root MSE	0.99721	**R-Square**	0.0056
Dependent Mean	2.65E-18	**Adj R-Sq**	0.0056
Coeff Var	3.76E+19		

Parameter Estimates							
Variable	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Type I SS**	**Type II SS**
Intercept	1	-2.23E-15	0.00491	0	1	0	2.06E-25
BMI	1	-0.07486	0.00491	-15.25	<.0001	231.41485	231.41485

Model 2

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	396.10522	198.0526	199.96	<.0001
Error	41287	40893	0.99045		
Corrected Total	41289	41289			

Root MSE	0.99522	R-Square	0.0096
Dependent Mean	-8.15E-17	Adj R-Sq	0.0095
Coeff Var	-1.22E+18		

Parameter Estimates							
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Type I SS	Type II SS
Intercept	1	1.50E-14	0.0049	0	1	0	9.25E-24
BMI	1	0.34621	0.03302	10.48	<.0001	231.4149	108.88452
BMI^2	1	-0.42578	0.03302	-12.89	<.0001	164.6904	164.69037

Model 3

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1531.53842	1531.538	1590.5	<.0001
Error	41288	39757	0.96293		
Corrected Total	41289	41289			

Root MSE	0.98129	R-Square	0.0371
Dependent Mean	-8.15E-17	Adj R-Sq	0.0371
Coeff Var	-1.20E+18		

Parameter Estimates							
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Type I SS	Type II SS
Intercept	1	2.59E-15	0.00483	0	1	0	2.78E-25
Fitness	1	0.1926	0.00483	39.88	<.0001	1531.538	1531.53842

Model 4

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	9205.66091	2301.415	2961.47	<.0001
Error	41285	32083	0.77712		
Corrected Total	41289	41289			

Root MSE	0.88154	R-Square	0.223
Dependent Mean	-8.15E-17	Adj R-Sq	0.2229
Coeff Var	-1.08E+18		

Parameter Estimates							
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Type I SS	Type II SS
Intercept	1	1.02E-14	0.00434	0	1	0	4.30E-24
SES	1	0.43179	0.00437	98.75	<.0001	8343.896	7577.7646
Fitness	1	0.1364	0.00485	28.15	<.0001	810.8849	615.67191
BMI	1	0.22937	0.02927	7.84	<.0001	0.38432	47.72557
BMI^2	1	-0.23679	0.02938	-8.06	<.0001	50.49566	50.49566