DOT HS-805 727

METHODS FOR ESTIMATING EXPECTED BLOOD ALCOHOL CONCENTRATION

Marcelline Burns
Herbert Moskowitz

Southern California Research Institute
6305 Arizona Place
Los Angeles, CA 90045

Contract No. DOT HS-8-01999
Contract Amt. $109,200

DECEMBER 1980
FINAL REPORT

Prepared For
U.S. DEPARTMENT OF TRANSPORTATION
National Highway Traffic Safety Administration
Washington, D.C. 20590

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DOT-HS-805-727		

4. Title and Subtitle	5. Report Date
Methods for Estimating Expected Blood Alcohol Concentration	December 1980
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Marcelline Burns and Herbert Moskowitz	
9. Performing Organization Name and Address	10. Work Unit No.
Southern California Research Institute 6305 Arizona Place Los Angeles, CA 90045	11. Contract or Grant No. DOT-HS-8-01999
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
SAME AS ABOVE	Final Report, Part II August 1978 - June 1980
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

Estimates of blood alcohol concentration (BAC) typically are based on the amount of alcohol consumed per pound bodyweight. This method fails to consider food intake and body composition, which significantly affect BAC. A laboratory experiment was conducted to examine amount and type of food and time of food intake in relation to alcohol intake and BAC. Protein and carbohydrates were more effective than fatty food in reducing the BAC expected in a fasted state. Moderate to large amounts of food, such as a typical full meal, were more effective than lesser amounts, but a small amount of food had some effect. Time intervals of ½ to 4 hours between eating and drinking were studied; the ½ hour interval was most effective in an inverse relationship. At 4 hours there was no food effect. In a study of body composition and BAC, 20 men and women were subjects. Estimates of percent body fat were calculated using body circumferences or skinfolds. Subjects were given .68 g alcohol/Kg bodyweight, and the relationship of BAC to body fat estimate was analyzed. The method of BAC estimates based on body fat estimates may be useful for scientific purposes but appears not to be feasible for widespread use. The data suggest that, compared to men, women will reach the same BAC with 15% less alcohol, based on ounces of alcohol per pound weight. The overweight person will reach the same BAC as an average weight person with 10% less alcohol. These findings reflect male-female differences in body composition and the higher percent fat in the obese body.

17. Key Words	18. Distribution Statement
alcohol, food effects, BAC estimate body composition, adipose tissue, BAC - body fat, BAC - food.	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	103	

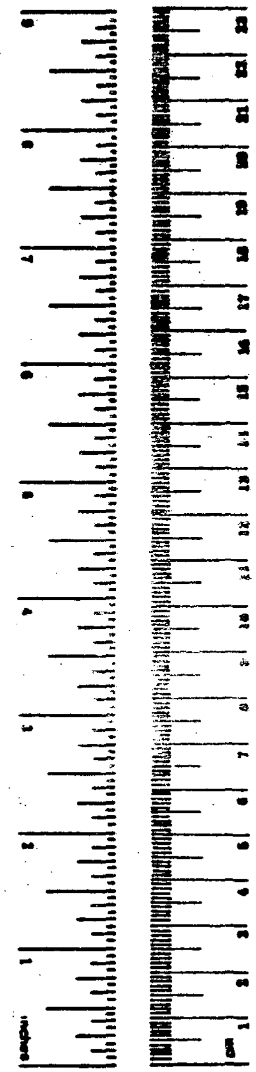
Form DOT F 1700.7 (8-69)

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

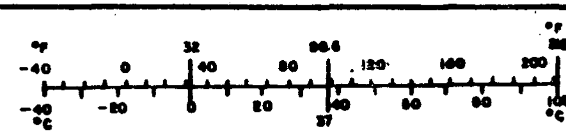


TABLE OF CONTENTS

List of Tables

List of Figures

I. Introduction

The overall objective of this study, Parts I and II, was the development of improved methods for estimating blood alcohol concentration (BAC). It is believed that many drivers risk unsafe driving after drinking alcohol, not only because they fail to understand the relationship of alcohol to driving impairment, but also because they do not know how to accurately estimate their own BACs. A specific goal of Part II of this study was to develop more accurate methods for estimating BAC based on the inclusion of estimates of percent body fat.

The fundamental principles on which to base an accurate BAC calculation are well known. It has been amply demonstrated that after alcohol equilibrium is attained (i.e., when alcohol has had sufficient time to be distributed throughout the body), the alcohol is distributed uniformly in the water of the body. For any organ of the body the quantity of alcohol to be found in that organ will be proportional to the amount of water which that organ contains in relationship to the general distribution of water in the body.

The body consists of two major compartments, lean body mass and fat (or adipose) tissue. In the adult, approximately 72% of the lean body mass is water and only 28% of the lean body mass consists of solids. On the other hand, the compartment of the body that is fat contains relatively little water, ranging from 10% to 30% of its weight (Keys and Brožek, 1953) with 70% to 90% being solids. Thus, if an individual had no fat, the determination of BAC for a given alcohol dose would be very simple. One would merely weigh the individual, assume that 72% of that weight was water and determine the BAC by dividing the alcohol dose by 72% of the bodyweight. Even if the percent of the body that is fat were relatively constant, BAC estimates would then be straightforward calculations.

There are, of course, no individuals who are entirely fat free, and the proportion of fat varies widely between individuals. For example, there are large differences between men and women, as well as differences due to eating patterns. If a simple method were available to determine the proportion of an individual's body which is fat, it would be comparatively easy to take that into account in the calculation of BAC, and thus improve the accuracy of the estimate of the BAC.

At the present time, BAC estimates usually are based on total bodyweight. Tables are widely available which present the predicted BAC as a linear function of number of drinks and pounds bodyweight. The objective of this study was to determine whether other body characteristics, such as percent body fat, can be used to increase the accuracy of BAC predictions.

II. Laboratory Study

A laboratory study was designed to examine the relationship of body fat estimates and BAC. The key issue is whether the body fat estimates will assist in predicting BAC.

The literature describes a variety of approaches to the problem of estimating body fat. Only those requiring relatively simple measures and apparatus were potentially suitable for the purposes of the study. Two types of measurements were taken, skinfolds and circumferences. The sites chosen for the measurements were those consistently recommended in the literature as good predictors of body fat. Four estimates of percent body fat were calculated, two using body circumferences and two using skinfolds. Details of the methods for making the body measurements and calculating estimates of body fat are presented in Appendix I.

METHODS

Study Design

Forty subjects, 20 men and 20 women, participated in the study, coming to the SCRI laboratory for one day-long session. Skinfolds and body circumferences were measured, and these measures were used subsequently to calculate estimates of body composition. An alcohol treatment, calculated on the basis of bodyweight, was administered, and BACs were monitored by gas chromatography throughout the course of the alcohol curve. The relationship of obtained BAC and body fat estimates was then examined.

Subjects

Subjects for the laboratory experiment were 20 men, ages 21-39 years (mean age 27.25 years), and 20 women, ages 21-46 years (mean age 28.20 years). They were paid for their participation in the experiment.

Subjects were recruited through state and college employment offices and were screened by telephone and in-person interviews for health status, drinking practices and drug use. No health problems were evident, and all subjects were moderate to low-heavy drinkers as categorized by the Cahalan, Cisin and Crossley (1969) scale of quantity and frequency of alcohol consumption. Light to moderate use of recreational drugs was reported, but there was no evidence of heavy drug use and abuse.

An even distribution of underweight, average weight and overweight individuals was selected from the pool of applicants.

The weight range for women was 80-181 lbs (36-82 Kg) with a mean weight of approximately 137 lbs (62 Kg). The weight range for men was 124-239 lbs (56-108 Kg) with a mean weight of approximately 165 lbs (74 Kg). A scatter plot of weight vs. height appears as Figure 1, Appendix II.

An effort was made to obtain samples of male and female subjects which were roughly equivalent in terms of the number of overweight, normal weight, and underweight persons. In order to later evaluate obtained BAC differences between the men and women, a comparison of the body composition of the two groups was required.

One approach to such an evaluation is a comparison of actual weights with "desirable weights", for example, the Metropolitan Life Insurance values (Williams, 1977). This requires an assessment of frame size, which was obtained in the laboratory as both the subject's and the Research Assistant's subjective judgement. Where a difference of opinion occurred, the wrist circumference was used as an additional indicator of frame size. If some uncertainty remained, the Research Assistant's assessment was accepted on the premise that the individual's own judgement was more likely to be biased. For example, the overweight person may like to believe that a large frame justifies excess pounds.

It is important to note the limitations of insurance weight tables. They were derived from insurance applicants under a wide variety of conditions. There are likely to be inaccuracies in the data base, and to view the tabled weights as actually being ideal or desirable may be unwarranted. However, for comparing the male and female subjects in this study, the tables will suffice since any source of error is likely to be a constant applying equally to both sexes.

The so-called desirable weight for a given frame size and height is tabled by sex as a range of weights. The number of laboratory study subjects who fell within and outside that range appears below.

	Men	Women
Actual weight within tabled range	6	6
Actual weight above tabled range	8	8
Actual weight below tabled range	6	6

Viewed in this way the two distributions are identical. However, looking at the data in a slightly different way changes that picture. If the midpoint of each tabled range of pounds is taken as the exact ideal weight for a given frame size and height, the women appear to be more overweight than the men. The mean differences between the actual weights of the subjects and the midpoints of the tabled ranges are given in the following.

	Men	Women
Actual weights minus midpoint of tabled range ($\bar{X}$ lbs)	+ 7.25	+10.18
Subjects whose weight <u>exceeded</u> midpoint of tabled range: Actual weights minus midpoint of tabled range ($\bar{X}$ lbs)	+25.80 (n=10)	+29.35 (n=10)
Subjects whose weight was <u>less</u> than midpoint of tabled range: Actual weights minus midpoint of tabled range ($\bar{X}$ lbs)	-11.30 (n=10)	- 9.00 (n=10)

Thus it appears that the group of female subjects was more overweight, less underweight than the male subjects when evaluated in terms of a desirable or ideal weight.

Treatment

The alcohol dose was .68 g alcohol/Kg bodyweight. This amount of alcohol, administered to men, is expected to produce a mean peak BAC of 0.080% measured 30 minutes after the completion of drinking (i.e., 60 minutes after drinking begins). Since women typically have a higher percent body fat, the alcohol dose is expected to produce a higher BAC, approximately 0.092%. This issue will be discussed in detail in a later section of male-female differences in BAC.

The alcohol was given as a drink of 80-proof vodka and orange juice mixed in a 1:1.5 ratio. Subjects were instructed to pace the consumption of the alcohol beverage evenly over the 30 minute drinking period, and they were monitored to insure compliance. A gas chromatograph (Intoximeter Mark IV) was used to measure the BACs by analysis of breath samples at 15 minute intervals for the first 1-1/2 hour post-dose and at 30 minute intervals thereafter.

Procedures

Subjects were required to abstain from food, alcohol and drugs following dinner of the evening preceding the laboratory session. Upon arrival at the laboratory, they were processed with standard intake procedures which included obtaining informed consent for participation, verification of alcohol use, verification of height and weight, instruction in the breath sampling procedure, obtaining a pretreatment BAC, and briefing on body measurement procedures. When subjects were scheduled, they were asked to wear to the laboratory clothing which would facilitate accurate and consistent body measurements. Skinfolds were measured at four sites, the biceps, triceps, subscapula, and suprailiac. Measured circumferences included waist, girth, thigh, arm, calf and buttocks.

When the body measurements had been obtained, the alcohol beverage was given. The drink was finished in 30 minutes, and the first breath sample was obtained 15 minutes later. A curve of the BAC was plotted as the machine readings were obtained. When it was evident that the curve was reflecting a declining, post-absorptive phase, the subject was given lunch. This occurred 90 to 120 minutes after completion of the drink. Subjects were released from the laboratory when the BAC declined below 0.03%.

In addition to the machine readings of BAC, the BAC at Time_0 was calculated. The peak BAC is the measure which the consumer is likely to be interested in and to understand, i.e., the highest level of alcohol which he/she will reach. However, peak BAC is confounded with time and individual absorption rates, occurring after differing periods of elapsed time for different individuals, and thus it is not the best index of alcohol level for purposes of analysis and comparison. The Time_0 BAC avoids these difficulties. This is the BAC which would occur if all the alcohol were instantly distributed throughout the body.

The Time_0 BAC is obtained with linear regression analysis ($y = a_0x^0 + a_1 0$; y = BACs as measured by gas chromatograph, x = time of BAC measurements). All post-absorption BACs for a subject were entered into the analysis, the constants a_0 and a_1 were obtained, and these were used to calculate a Time_0 BAC for the subject. This is a theoretical measure of the BAC that would occur if the alcohol all entered the system instantaneously, and thus it avoids the problem of differing absorption times.

RESULTS

The 20 male subjects reached a mean peak BAC of 0.082%. The 20 female subjects reached a mean peak BAC of 0.097%. The mean Time_0 BAC for men was 0.101%; for women it was 0.117% (Table 6, Appendix II).

Estimation of Body Fat

The body circumferences and skinfold measurements appear in Table 1, Appendix II. These measurements were used to calculate estimates of percent body fat for each of the 40 subjects, and the estimates appear in Table 2, Appendix II. Four estimates of percent fat were calculated for each person, two based on skinfolds and two using other body measurements. These body fat estimates, and various other body measures as well, were examined for correlational relationship with measured BAC.

Durnin and Rahaman (1967) and Durnin and Womersley (1974) tabled percent body fat as a function of the total of four skinfold measurements (Tables 1 and 2, Appendix I). The total of these four skinfold measurements for the study subjects, together with the corresponding estimates of percent fat derived from the tables appear in Table 1. The correlations of body fat estimates derived from the Durnin and Rahaman (1967) table and peak BAC are r = 0.63 for women and 0.65 for men. The correlations using the Durnin and Womersley (1974) values are r = 0.57 for women and 0.66 for men. These can be compared with r = 55 which is the correlation of bodyweight and peak BAC for both men and women. Other peak BAC - body measurement correlation coefficients are given in Table 2.

The Wright and Wilmore (1974) method for estimating body fat, described in Appendix I, works reasonably well for men; it was developed with males only. It does not yield satisfactory fat estimates for women. The Katch et al. (1979) method appears to give reasonably good estimates, although they possibly are less accurate than those obtained with skinfolds. Note, however, that all of these methods are relatively complicated and are not viewed as appropriate to recommend for widespread, general use. Note, too, that the evaluations of the methods can be made only in terms of expected percent fat, based on the ranges reported in the literature, or by comparing the estimates of one method to those obtained with another. There is no direct method for measuring percent body fat.

Seltzer and Mayer (1965) developed a "standard of obesity", based on the triceps skinfold (Table 3, Appendix I). Since the simplicity of a single measure has considerable appeal, the measured triceps skinfold for the subjects was compared to this obesity standard, as shown in Table 3. It was found that the method offers no improvement in BAC prediction over that which can be obtained from bodyweight alone. Correlations for BAC and the amount by which the subjects' triceps differend from the obesity standard are 0.52 for women and 0.50 for men.

To further examine the feasibility of using a single body measure to estimate percent body fat, stepwise linear regression analyses were carried out. Separate body measures were entered into a regression analysis as independent variables with an estimate of percent fat as the dependent variable, using Biomedical Computer

TABLE 1

Four Skinfolds (Total mm) and Estimates of Body Fat by Two Methods
Male Subjects

SUBJECT NO.	PEAK BAC	SKINFOLDS TOTAL (mm)	% FAT DURNIN & RAHAMAN (1967)	% FAT DURNIN & WOMERSLEY (1974)
20	.084	59.25	21.85	23.35
21	.094	80.00	26.00	24.80
22	.077	27.75	12.60	11.82
23	.073	26.25	12.00	11.10
24	.085	42.25	17.68	16.99
25	.079	85.50	26.60	25.57
26	.104	80.75	26.08	24.91
27	.070	48.00	19.40	18.48
28	.062	19.00	8.30	7.44
29	.097	48.00	19.40	18.48
30	.079	47.50	18.95	18.09
31	.090	45.67	18.70	20.54
32	.079	43.25	17.98	17.25
33	.074	27.75	12.60	15.30
34	.085	36.00	15.80	15.04
35	.096	48.75	19.63	21.23
36	.071	42.75	17.83	17.12
37	.077	43.00	17.90	19.92
38	.074	40.75	17.23	16.60
39	.080	46.00	18.80	17.96

TABLE 1

Four Skinfold (Total mm) and Estimates of Body Fat by Two Methods
Female Subjects

SUBJECT NO.	PEAK BAC (%)	SKINFOLDS TOTAL (mm)	% FAT: DURNIN & RAHAMAN (1967)	% FAT: DUPNIN & WOMERSLEY (1974)
40	.106	42.17	25.15	24.09
41	.111	39.00	24.20	25.14
42	.087	25.50	18.75	17.07
43	.100	31.50	21.60	20.10
44	.080	42.00	25.10	24.04
45	.107	36.00	23.30	21.88
46	.097	58.50	29.70	30.24
47	.080	29.00	20.50	18.96
48	.117	84.00	34.80	33.82
49	.096	28.00	20.00	18.42
50	.104	56.00	29.20	28.06
51	.092	36.50	23.45	24.24
52	.106	35.00	23.00	21.50
53	.099	37.00	23.60	22.26
54	.089	27.00	19.50	23.12
55	.100	34.00	22.60	21.10
56	.101	33.50	22.40	23.13
57	.077	17.50	14.25	17.00
58	.106	93.75	36.38	35.40
59	.093	39.25	22.80	25.23

TABLE 2

Summary of Correlations
BAC and Body Composition Estimates

PEAK BAC AND:	METHOD OF ESTIMATION	r WOMEN (N=20)	r MEN (N=20)
Percent Fat	Katch et al. (1979)	0.45	0.67
Percent Fat	Durnin & Rahaman (1967)	0.64	0.65
Percent Fat	Durnin & Womersley (1974)	0.56	0.66
Lean Body Weight	Wright & Wilmore (1974)	0.52	0.35
Lean Body Weight	Katch et al. (1979)	0.53	0.28

Significance levels for Coefficients (r):

$df_{(n-2)} = 18$	.01	.56
	.05	.44

TABLE 3

Comparison: Triceps Measurements and Obesity Standard*
Male Subjects

SUBJECT NO.	TRICEPS SKINFOLD (mm)	OBESITY STANDARD* (triceps,mm)	DIFFERENCE (triceps minus standard)
20	29.85	23	6.85
21	46.99	18	28.99
22	10.16	17	-6.84
23	17.15	20	-2.85
24	19.69	20	-0.31
25	29.21	22	7.21
26	32.39	22	10.39
27	27.31	22	5.31
28	10.16	11	-6.84
29	29.21	20	9.21
30	22.23	18	4.23
31	27.94	23	4.94
32	33.02	22	11.02
33	10.80	23	-12.20
34	20.32	20	0.32
35	21.59	23	-1.41
36	25.40	18	7.40
37	25.40	23	2.40
38	17.78	20	-2.22
39	15.88	20	-4.12

*Seltzer and Mayer (1965). See Table 1, Appendix 1.

TABLE 3

Comparison: Triceps Measurements and Obesity Standard*
Female Subjects

SUBJECT NO.	TRICEPS SKINFOLD (mm)	OBESITY STANDARD* (triceps, mm)	DIFFERENCE (triceps minus standard)
40	29.21	29	0.21
41	27.54	30	-2.46
42	6.35	29	-22.65
43	29.21	28	1.21
44	26.67	28	-1.33
45	26.67	29	-2.33
46	46.99	30	16.99
47	24.13	29	4.87
48	52.07	28	24.07
49	17.78	29	-11.22
50	36.83	29	7.83
51	31.75	30	1.75
52	26.67	29	-2.33
53	29.21	28	1.21
54	21.59	30	-8.41
55	33.02	29	4.02
56	24.13	30	-5.87
57	11.43	30	-18.57
58	62.23	29	33.23
59	22.86	30	-7.14

*Seltzer and Mayer (1965). See Table 1, Appendix 1.

Program P2R (Dixon and Brown, 1977). The estimates of percent fat had been obtained with methods which require several body circumferences or skinfolds. The regression analysis was of interest in determining how well those estimates could be predicted with only one or two body measures.The regression results for the data for 40 laboratory subjects are summarized in Table 4, showing four separate regression analyses each for men, women, and all subjects. The table shows the individual measurement entered at each step and the multiple R at that step. For example,note that the predicted percent fat for men, using only the abdomen circumference correlates with R = 0.95 with the fat estimate derived from the Katch et al. (1979) tables.

Sex Differences

Because of the differences in body composition it was necessary to analyze all of the laboratory experiment data separately for male and female subjects. Men and women on the average differ by at least 10% in the proportion of the body which is estimated to be fat. A difference of that magnitude would be expected to also produce a difference in BAC.

The *t* statistic data, testing differences between men and women, are presented in Table 5. The female subjects with a significantly higher estimated percent body fat also reached significantly higher BACs. The mean estimated percent fat for the women is approximately 25%, compared to an estimate of 18% for the men. The BACs differ significantly whether measured as the peak BAC, as the mean of the BAC readings over 240 minutes post-treatment, or as the rate of BAC decrease.

The question which follows is whether the difference in estimated fat accounts for the obtained BAC differences between men and women, or whether other gender-related differences may also be acting to cause the differences in BAC. Although a definitive answer to the question cannot be provided on the basis of limited data, the calculations presented in Table 6 suggest a causal relationship in the observed female-male differences in BAC and body composition. Note that the male/female ratios for pounds of fat and measured BAC both are 0.85. Further, the mean percent BAC per pound of fat is 0.0056% for both men and women. These data suggest that the proportion of the body which is fat is a primary cause of women reaching a higher BAC than men. The 0.85 ratio may be close to a true population value. Note that it is estimated that 49% of a woman's bodyweight is water and 58% of a man's bodyweight is water (Olesen, 1965). In this instance, the female/male ratio also is 0.85.

Figures 1 and 2 display the Time_0 BACs for the 20 male and 20

TABLE 4

Summary: Stepwise Linear Regression Analyses

Analysis for:	Dependent Variable: Estimate of Body Fat (Calculation Method)	Independent Variables: Single Body Measures	R
Male Subjects	Katch et al. (1979) Body Circumferences	Abdomen circumference	.9499
		Right Forearm circumference	.9641
		Upper Arm circumference	.9880
		Suprailiac skinfold	.8465
	Durnin and Rahaman (1967) Skinfolds	Abdomen circumference	.8759
		Suprailiac skinfold	.9226
		Triceps skinfold	.9764
		Biceps skinfold	.9835
Female Subjects	Katch et al. (1979) Body Circumferences	Rt. Thigh circumference	.9235
		Abdomen circumference	.9749
		Rt. Forearm circumference	1.0000
		Suprailiac skinfold	.8046
	Durnin and Rahaman (1967) Skinfolds	Abdomen circumference	.9694
		Biceps skinfold	.9436
		Triceps skinfold	.9818
		Subscapular skinfold	.9860

TABLE 4 (continued)

Summary: Stepwise Linear Regression Analyses

Analysis for:	Dependent Variable: Estimate of Body Fat (Calculation Method)	Independent Variables: Single Body Measures	R
All Subjects	Katch et al. (1979) Body Circumferences	Abdomen circumference	.5575
		Rt. Forearm circumference	.7718
		Biceps skinfold	.7246
		Triceps skinfold	.7510
	Durnin and Rahaman (1967) *Skinfolds*	Abdomen circumference	.4606
		Rt. Forearm circumference	.6316
		Triceps skinfold	.8636
		Biceps skinfold	.9037

TABLE 5

Comparisons of Data for Men and Women
Summary of t Statistic

VARIABLE	$\bar{X}$ WOMEN	$\bar{X}$ MEN	t
Age	28.20 yrs	27.25 yrs	0.59
Peak BAC	.097%	.082%	4.73**
Mean of BAC readings 30-240 minutes	.067%	.055%	3.06**
Hours from Peak to ≤ .03% BAC	3.32 hr	2.89 hr	1.97*
BAC decrease/hr (Peak → ≤ .03%)	.021%	.019%	2.71**
Δ BAC (Peak → ≤ .03%)	.069%	.053%	4.63**
Percent Fat:			
Katch et al. method (1979)	26.13%	18.68%	2.90**
Skinfold (Durnin & Rahaman method, 1967)	24.01%	18.27%	3.66**
Skinfolds (mm):			
Biceps	6.75	4.89	2.09*
Triceps	11.50	9.30	1.59
Suprailiac	11.50	18.85	3.17**
Subscapula	11.28	13.83	1.39
Total	41.02	46.86	1.00

t statistic for two means· 1 tail, 18 df $t_{.99}$ 2.55**
$t_{.95}$ 1.73*

TABLE 6

Comparisons of Data for

Men and Women

	Men	Women	Ratio Men: Women
Fat Weight*, $\bar{X}$, Pounds	14.72	17.33	14.72/17.33 = .85
BAC $\bar{X}$, %	.082%	.097%	.082%/.097% = .85
$\bar{X}$ BAC/Lbs. Fat	.0056%	.0056%	

* Katch et al. method of estimating fat weight.

Figure 1: Time 0 BACs and Bodyweights for Twenty Female Subjects

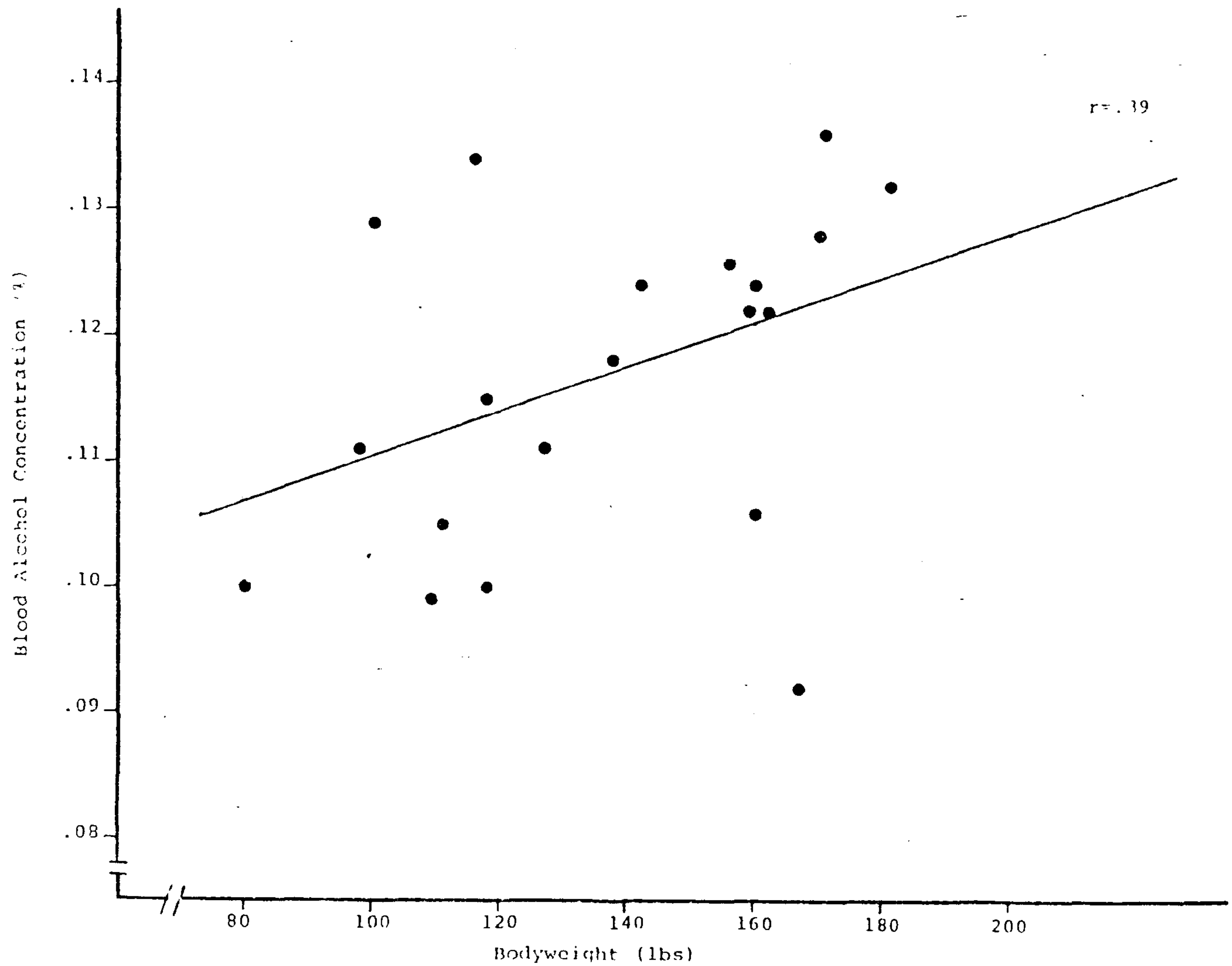
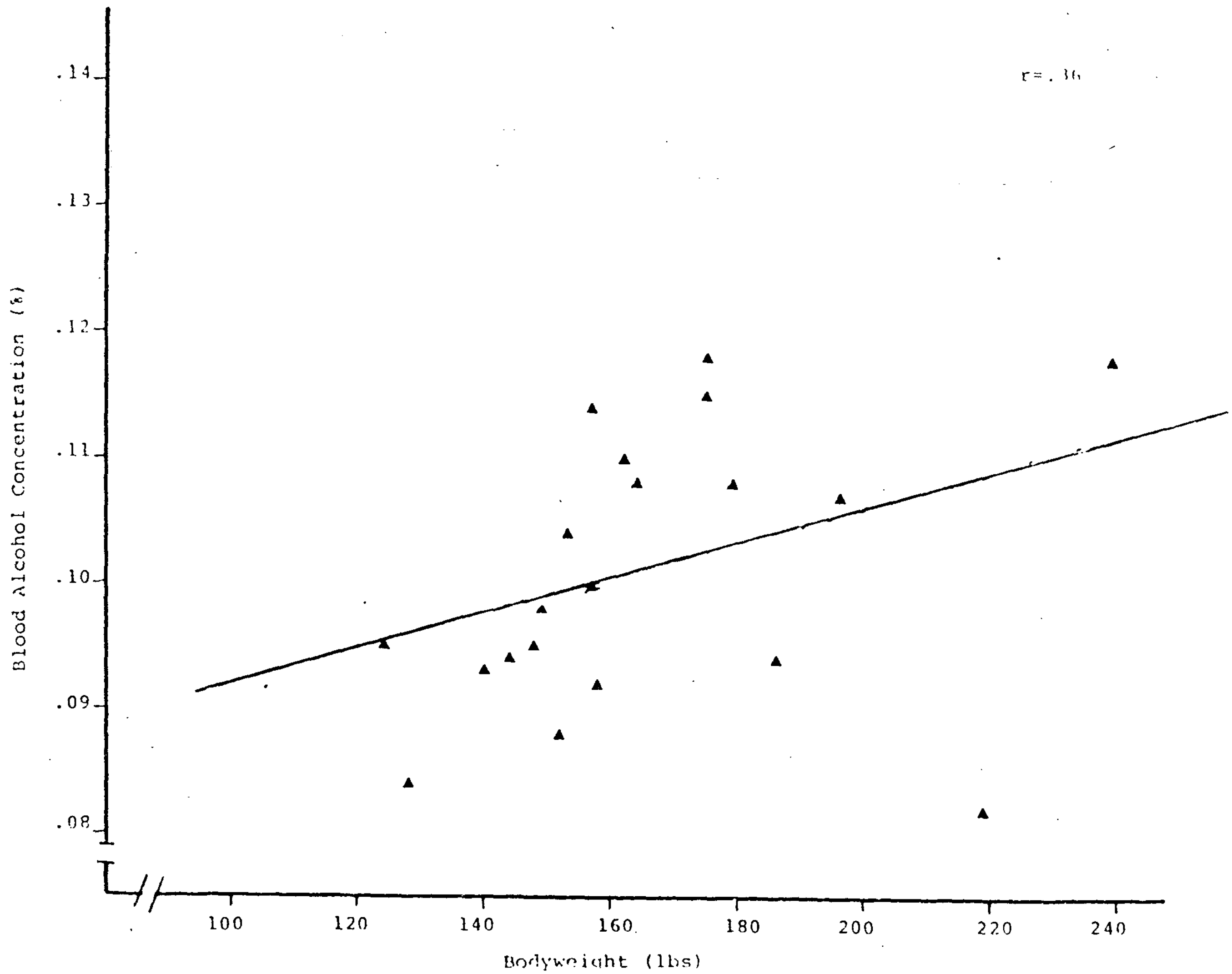


Figure 2: Time 0 BACs and Bodyweights for Twenty Male Subjects



female subjects plotted versus bodyweight. Figures 3 and 4 show the same BACs in a scatter diagram with the best estimate of percent body fat. Figures 5 and 6 plot the $Time_0$ BACs versus pounds underweight/overweight. For the latter analysis, each individual's weight was characterized in terms of the number of pounds over or under the weight he or she should be, according to a standard height-weight table. The relationship of BAC to these various indices of body composition is further summarized in Table 7, correlations of $Time_0$ BAC and body fat estimates, and in Table 8 which summarizes linear regression analyses of BAC and body composition measures.

Figure 3: Time 0 BACs and Estimates of Percent Body Fat for Twenty Female Subjects

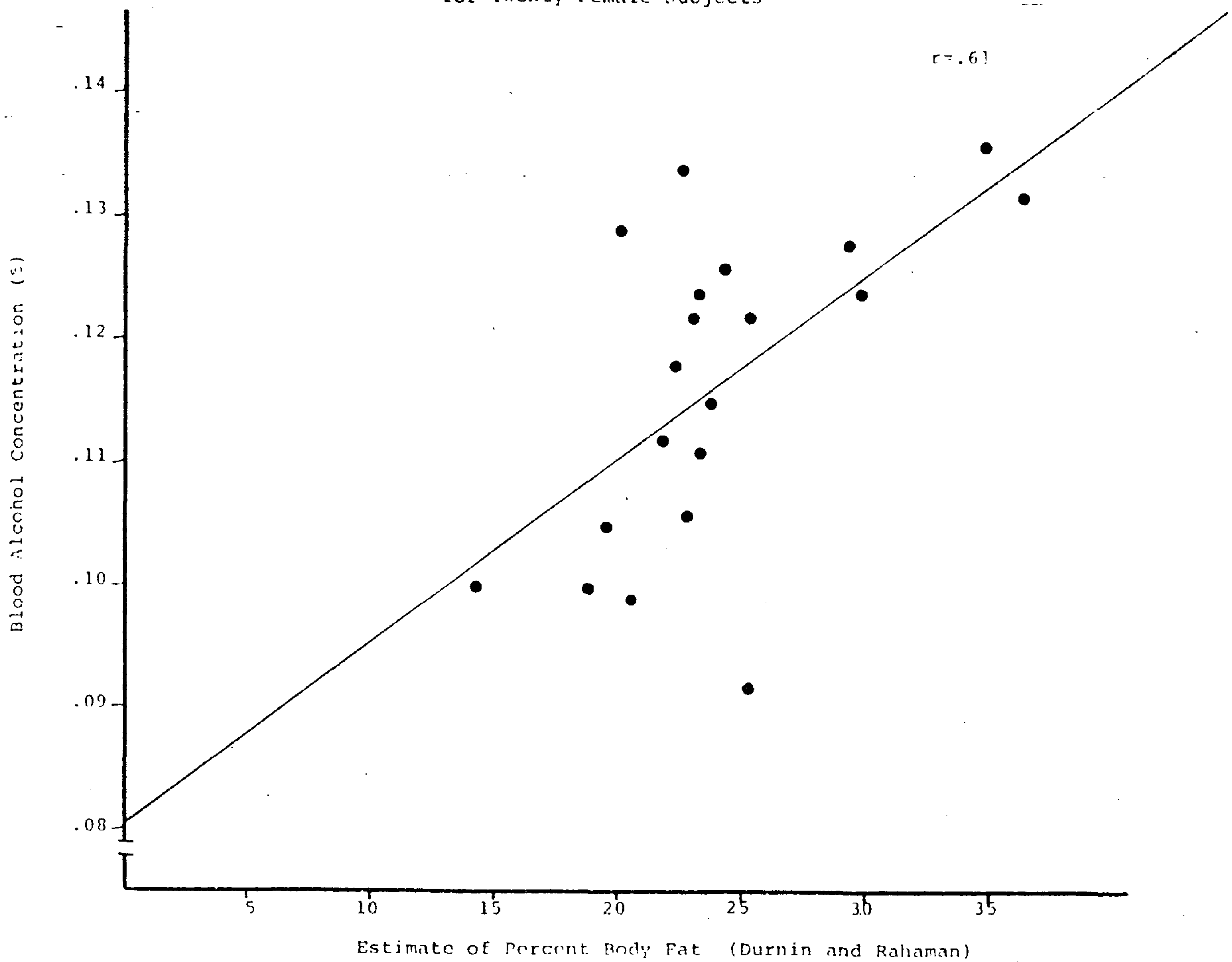


Figure 4: Time 0 BACs and Estimates of Percent Body Fat for Twenty Male Subjects

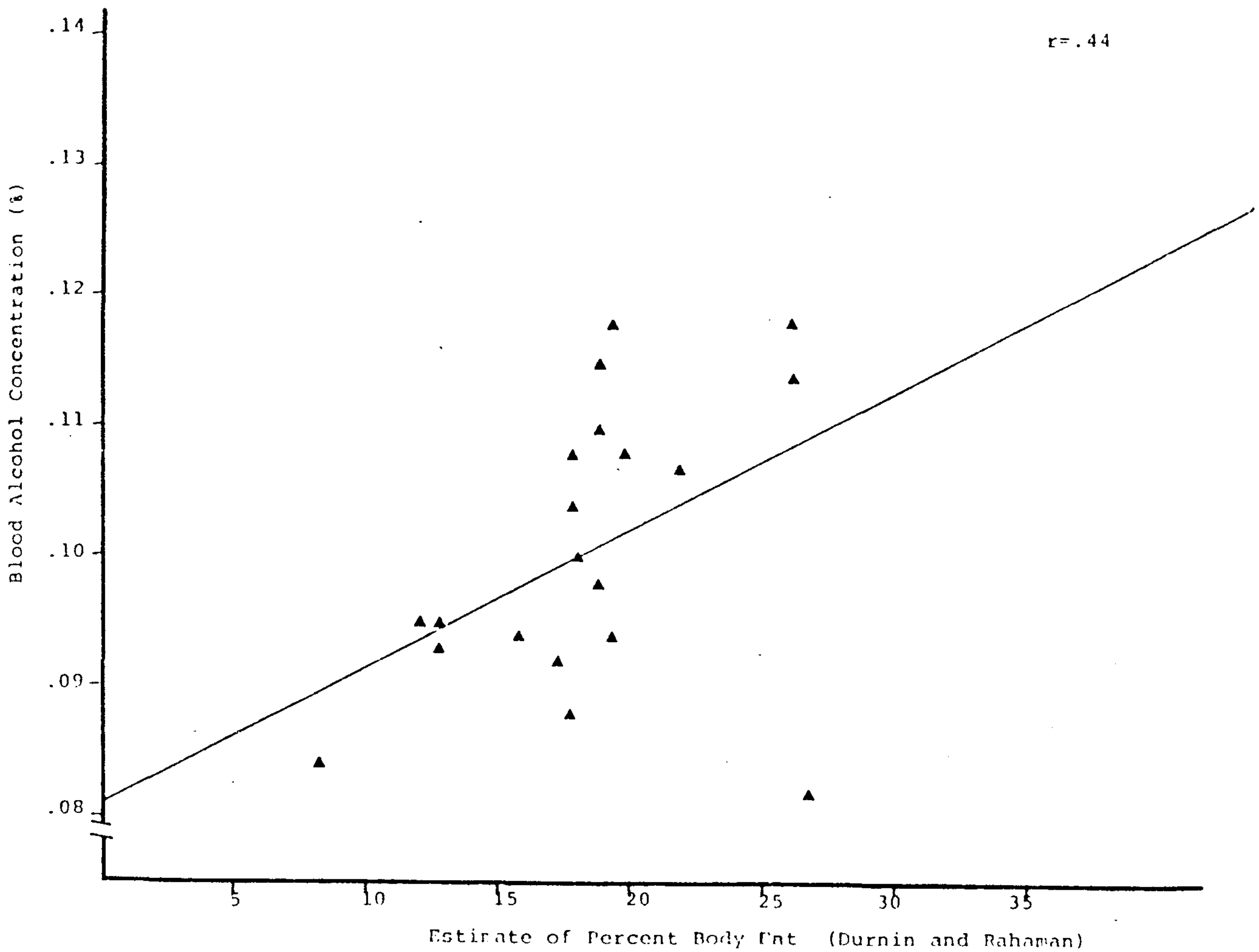


Figure 5: Time 0 BACs and "Lbs. Underweight or Overweight" for Twenty Female Subjects

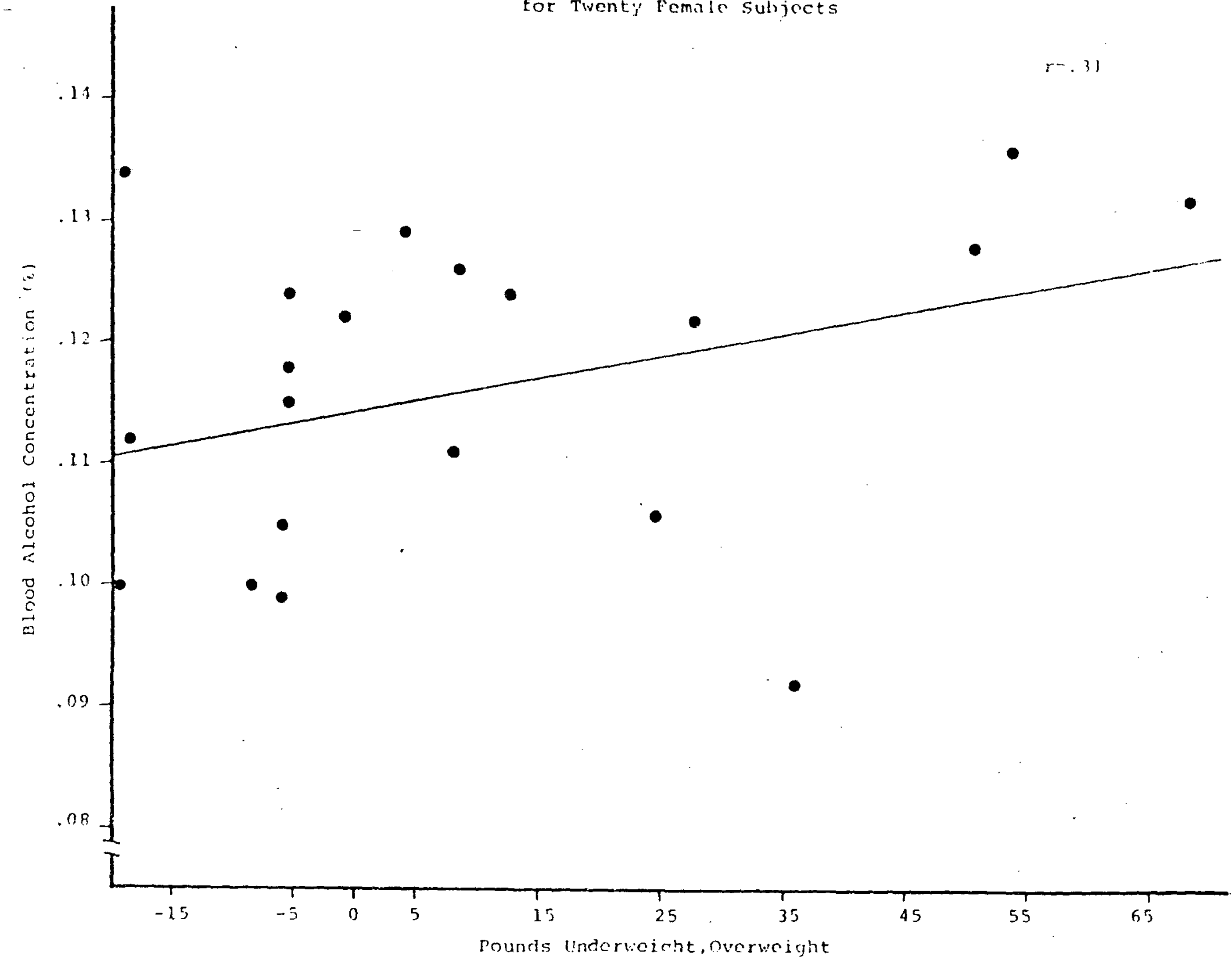


Figure 6: Time 0 BACs and "lbs. Underweight or Overweight" for Twenty Male Subjects

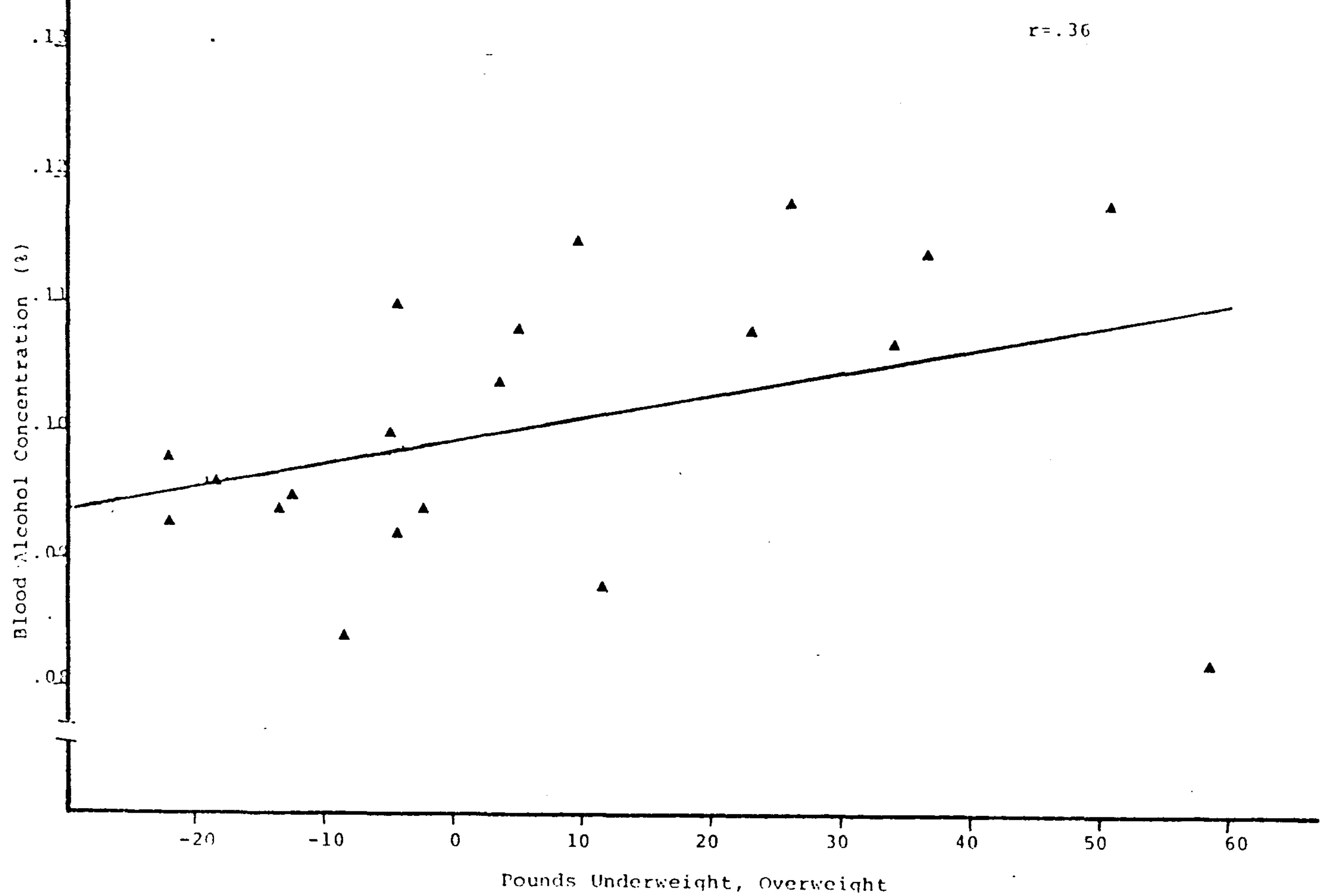


TABLE 7

Summary of Correlations
BAC at $Time_0$ and Body Fat Estimates

$TIME_0$ BAC AND:	METHOD OF ESTIMATION	r WOMEN (N=20)	r MEN (N=20)
Skinfolds	Durnin & Rahaman (1967)	0.61	0.44
Skinfolds	Durnin & Womersley (1974)	0.53	0.49
Circumferences	Wright & Wilmore (1974)	0.33	0.62
Circumferences	Katch, McArdle, & Boylan (1979)	0.39	0.44
Obesity Standard Method	Seltzer & Mayer (1965)	0.57	0.43
Total Bodyweight		0.39	0.36

Significance levels for Coefficients (r):

$df_{(n-2)} = 18$ .01   .56
.05   .44

III. Discussion

The purpose of this study was to determine whether the estimates of body fat, based on empirical body measurements, can provide better methods for predicting BAC than are obtained with methods currently in use. For this purpose, the best method for making reasonably good estimates of percent body fat is based on skinfold measures. Other precise methods require highly specialized laboratories and the skills to carry out hydrostatic weighing or chemical and tissue analysis and thus have no relevance to the issue of BAC estimation by the public or even by the general scientific community.

The measurement of skinfolds also requires considerable skill, as well as a scientific quality caliper. The folds must be measured at precisely-located sites on the body, following the correct procedures for lifting the skin and applying the caliper. Further, to interpret the skinfold measures, one must refer to tables of percent fat associated with the obtained measurements. In view of these requirements, it is concluded that the method is not appropriate for recommendation to the general public. However, skinfolds can be used to provide accurate and reliable body fat estimates in the setting of a medical office or scientific laboratory.

The problem then is to develop methods of predicting BAC which are not only accurate but are also practical. The information required for the various approaches to BAC estimation ranges from the difficult-to-obtain skinfold to measures of body circumferences to simple bodyweight. In the following discussion, the methods which had appeared to be the most promising are evaluated in terms of relative potential utility, either as a scientific method for use in laboratories or as a practical method to be widely used by the public.

Currently, many agencies concerned with highway safety advise the individual to refer to a table which presents predicted BAC as a function of the number of drinks and bodyweight. Figure 7 represents a typical table of this kind (Indiana Department of Motor Vehicles, 1974). It is based on the assumption that BAC is a linear function of the amount of alcohol consumed and the individual's total weight. The correction for the passage of time amounts to a 0.015% drop in BAC per hour. Under this assumption, two drinks consumed by a 100-lb person are predicted to produce the same BAC as four drinks consumed by a 200-lb person.

When this table was evaluated with data from the study subjects, the differences between the tabled BAC predictions and actual BACs were found to be large. The mean error was +0.044% for the men and +0.023% for the women. These values were obtained

Figure 7 : BAC Prediction Table

	BODY WEIGHT IN POUNDS								
DRINKS	100	120	140	160	180	200	220	240	IMPAIRMENT
1	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	
2	0.08	0.06	0.05	0.05	0.04	0.04	0.03	0.03	Rarely
3	0.11	0.09	0.08	0.07	0.05	0.06	0.05	0.05	
4	0.15	0.12	0.11	0.09	0.08	0.08	0.07	0.06	
5	0.19	0.16	0.13	0.12	0.11	0.09	0.09	0.08	Possibly
6	0.23	0.19	0.16	0.14	0.13	0.11	0.10	0.09	
7	0.26	0.22	0.19	0.16	0.15	0.13	0.12	0.11	
8	0.30	0.25	0.21	0.19	0.17	0.15	0.14	0.13	Definitely
9	0.34	0.28	0.24	0.21	0.19	0.17	0.15	0.14	
10	0.38	0.31	0.27	0.23	0.21	0.19	0.17	0.16	

Subtract 0.01 percent for each 40 minutes of drinking. One drink is 1 ounce of liquor, 12 ounces of beer, or a 3.5 ounce glass of wine.

Adapted from Indiana Driver Manual, Indiana Bureau of Motor Vehicles, 1974.

by entering the table with each individual's bodyweight and the amount of alcohol he or she was given. It frequently was necessary to interpolate since bodyweight is tabled in 20-lb increments, and amount of alcohol is given only in whole ounces (1 ounce/drink). Although the error in prediction was found to be consistently in the direction of overestimation which may be viewed as a 'safer' error than underestimation, it may also detract from the credibility of the table.

The evaluation of BAC prediction methods was continued with an examination of expected BACs for study subjects on the assumption that they were given standard doses rather than doses based on bodyweight. Figures 8 and 9 show the distribution of expected BACs assuming that the men were all given 51.0 g alcohol, and the women were all given 42.0 g alcohol. These doses are the means of the alcohol amounts which actually were administered to the subjects. The expected mean BAC for men under this average dose is 0.079% (σ = 0.015%), measured 60 minutes after the start of drinking. For women the predicted mean BAC is 0.098% (σ = 0.028%). The method by which the expected BACs were calculated is given in Appendix I.

Note that the average doses are expected to produce essentially the same BACs as were obtained when subjects were dosed with 0.68 g alcohol/Kg bodyweight. The mean peak BACs under this dose were 0.082% for men and 0.097% for women, each with σ = 0.010%. The important difference is that the standard deviations (σ), representing the error in predicting BAC, were reduced as a result of basing the doses on the subjects' weights. The question of interest then is whether the prediction of BAC can be still further improved by the addition of other information. Instead of basing prediction solely on bodyweight, can other indices of body composition be used to increase the accuracy of BAC prediction, either for scientific purposes or for use by the general public?

Note that Time_0 BACs correlated with bodyweight with r = 0.36 and r = 0.39 for men and women, respectively (Table 8). The importance of these correlations is that they appear in spite of having administered alcohol doses to the subjects by bodyweight. Since the alcohol was administered as grams alcohol per kilogram bodyweight (0.68 g alc/Kg B.W.), one would expect to obtain the same BAC for all subjects, and to find no relationship of measured BAC and weight. That these correlations occurred indicates some related body characteristic beyond weight. One interpretation of the finding is that the relatively lighter weight person typically is leaner whereas greater total weight is likely to mean also more body fat. A lean person has a greater proportion of body water into which the consumed alcohol is distributed. The body

Figure 8: Expected BAC for Twenty Male Subjects
Dose: 51.0 g Alcohol

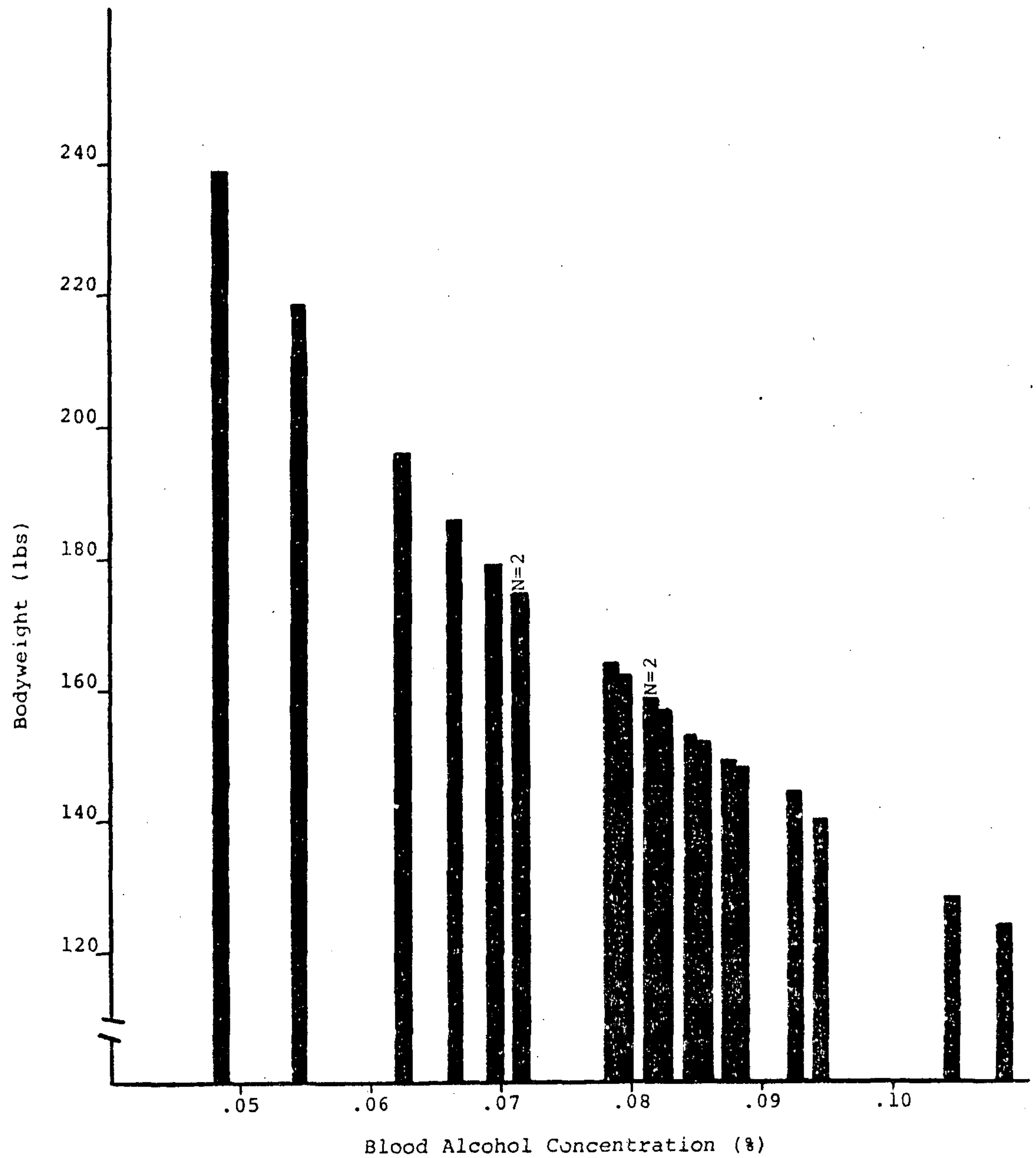


Figure 9: Expected BAC for Twenty Female Subjects
Dose: 42 g Alcohol

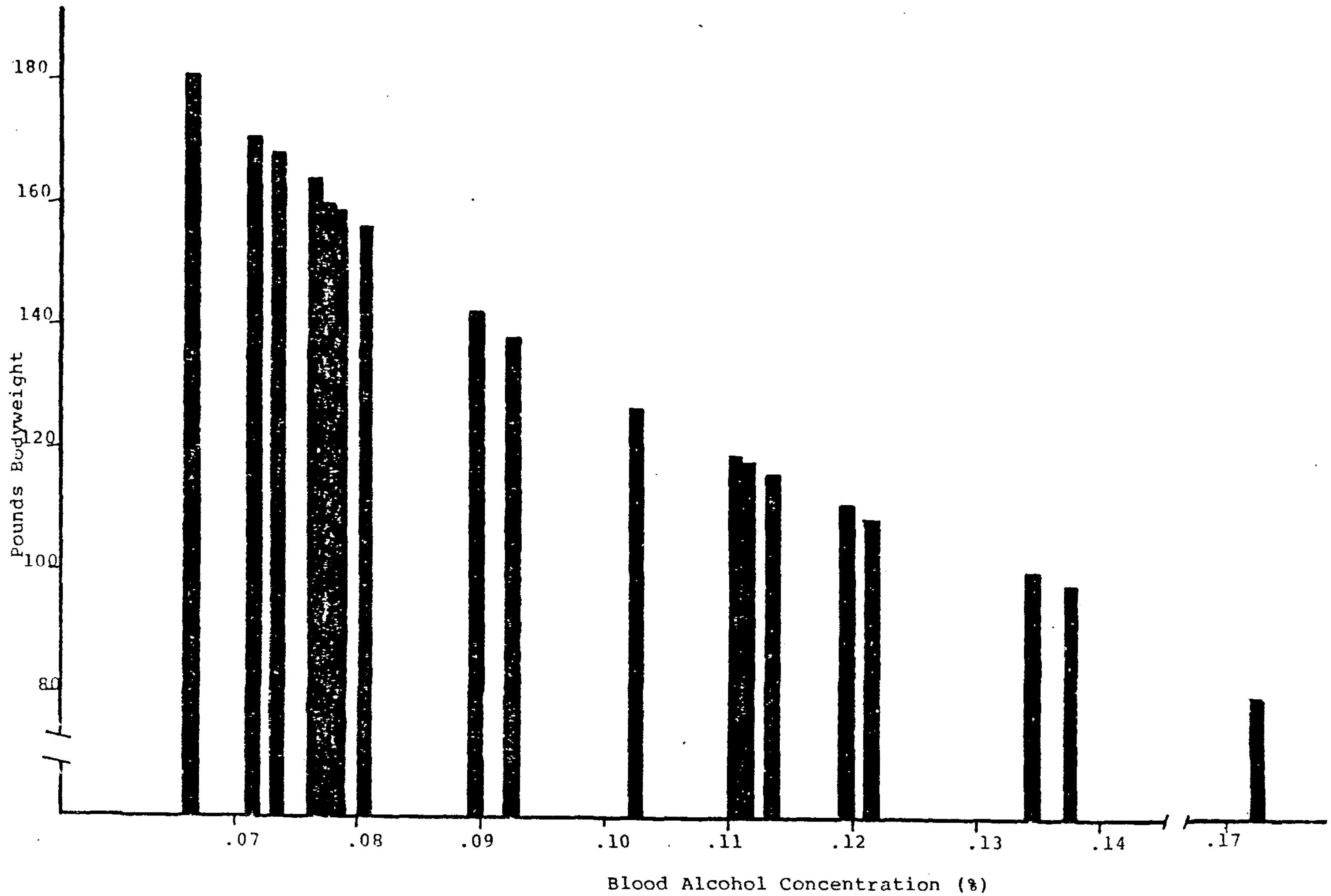


TABLE 8

Summary of Linear Regression Analyses
BAC and Body Composition Measures

BAC AND:	INTERCEPT MEN	INTERCEPT WOMEN	SLOPE MEN	SLOPE WOMEN	r MEN	r WOMEN	ACTUAL BAC - PREDICTED BAC: MEAN DIFFERENCE MEN	ACTUAL BAC - PREDICTED BAC: MEAN DIFFERENCE WOMEN	ACTUAL BAC - PREDICTED BAC: STANDARD DEVIATION MEN	ACTUAL BAC - PREDICTED BAC: STANDARD DEVIATION WOMEN
Bodyweight*	.078%	.093%	.0001	.0002	0.36	0.39	.008%	.009%	.010%	.012%
Percent Body Fat (estimated with skinfolds, Durnin and Rahaman method, 1967)	.082%	.080%	.0010	.0020	0.44	0.61	.007%	.008%	.010%	.010%
Pounds under or Over Standard Weight (Metropolitan Life Insurance Tables)	.100%	.115%	.0002	.0002	0.36	0.31	.008%	.010%	.009%	.012%

*Note that alcohol doses were calculated, on the basis of bodyweight, to produce a mean expected BAC of .08%. The relationship of BAC and bodyweight, reflected in the above analysis, occurred in spite of dosing by pounds of bodyweight.

with proportionately more fat, and thus less body water into which alcohol can be dispersed, will then reach a higher BAC when doses are based on total bodyweight. It appears that the assumption that BAC can be accurately predicted as a linear function of number of drinks and bodyweight will be incorrect for a great many people and that the linear hypothesis requires a correction. As noted earlier, it is concluded that the use of skinfold measures is a useful method when a high quality instrument is used by trained personnel. Time_0 BACs correlated with body fat estimates, based on skinfolds, with $r = 0.44$ for men and 0.61 for women. However, due to the difficulties in obtaining accurate skinfold measures, a more practical and easy-to-use method is required for recommendation to the public.

In further study of the 'lean-fat' body characteristic, the amount by which the subjects' weights deviated from normal weights was examined; i.e., the amount over or under the recommended weight for a given height and frame size. To examine the utility of this measure, the subjects' BACs have been plotted vs. bodyweights (Figures 1 and 2). These data show that the deviations from the predicted mean BAC tend to be systematically related to deviations from normal bodyweight (see also Table 6, Appendix II). Although all subjects were given the same alcohol dose per pound weight, those individuals below the average weight of the group more often reached a BAC below the predicted BAC, and those subjects who weighed above the average weight of the group more often reached a BAC above the predicted level.

It can be seen that the scatter plots of BACs vs. bodyweight (Figures 1 and 2) and the scatter plots of BACs vs. body fat estimates (Figures 3 and 4) are roughly the same. Also, in Figures 5 and 6, BACs are plotted vs. the underweight/overweight measure, and the distribution is similar to that obtained with body fat estimates. The summary of linear regression analyses in Table 8 shows that the BAC predictions obtained with the underweight/overweight variable are not as good as can be obtained with body fat estimates. However, a critical issue here is the utility of the various methods, and it must be kept in mind that the average person cannot make an accurate estimate of body fat but can readily calculate pounds over or under standard weights. The correlations of the two measures "percent body fat" and "pound underweight/overweight", are $r = 0.83$ for males and $r = 0.86$ for females, suggesting that they reflect the same body characteristics. It appears that the development of tables which present BAC estimates as a function of amount of alcohol consumed and pounds underweight or overweight may be a feasible approach to the improvement of BAC predictions.

There also is the potential, as discussed previously in this report, for developing formulae or tables which would present a body fat estimate as a function of a single body measure. These would be derived from linear regression analysis of body circumferences and skinfolds. The body fat estimates obtained in this way then could be used to improve BAC predictions, compared to those based on bodyweight. The difficulty with this approach is that the regression analysis will require body measurements for a very large number of subjects, and the improvement in estimation for the average person probably will not be large. However, such formulae or tables might lead to a significant improvement in BAC prediction for individuals who are obese or have otherwise atypical body composition.

An important and consistent finding throughout this study of body fat estimation methods and BAC prediction methods has been the significant differences between male and female subjects. The higher percentage body fat which characterizes the female body is reflected in higher BACs when all subjects are dosed with the same amount of alcohol per Kg bodyweight. If the BACs obtained for the female subjects in this study were adjusted in terms of the observed differences between men and women (BAC x 0.85, See pages 12.), the mean BAC for women would become 0.083% (σ =0.009%). Note that this is very close to the mean obtained BAC for the men at 0.082% (σ=0.010%). Based on this finding, an appropriate guideline for administering alcohol to women in laboratory experiments would be to give 85% of the dose calculated by bodyweight for men. In this study that would have reduced the dose to 0.58 g alcohol/Kg bodyweight for the female subjects. At minimum, it appears that tables of predicted BAC, based on number of drinks and bodyweight, must be amended to reflect this significant male-female difference.

IV. Conclusions

The following conclusions are based on data for the 40 subjects who were examined in this laboratory study.

A typical table of estimated BAC, which is based on the number of drinks and total bodyweight, produces an overestimate of the individual's BAC. Since women tend to reach higher BACs than men for a given amount of alcohol, the table error is generally smaller for women but nonetheless an overestimate. More accurate and more credible methods of prediction are needed for use by the general public.

The error in BAC predictions based on bodyweight is attributable principally to differences in body composition, specifically the proportion of the body which is fat. Body fat estimates can be used to improve the accuracy of BAC prediction, but obtaining the estimate of body fat is itself a difficult problem.

The best methods for estimating percent body fat were found to be those that are based on measurement of skinfolds. Again, however, the measurement itself presents a problem, and it is concluded that the skinfold method is potentially useful for clinical and laboratory settings, but that it is not feasible for widespread use by the public. As discussed in the preceding section, it appears that the measure "pounds underweight/overweight" also can be used to improve the accuracy of the BAC prediction, and unlike the estimate of body fat, it is a measure readily obtainable by the average person.

V. Recommendations

It is recommended that further research be directed to the development of BAC estimate tables which will be more accurate than those currently available. The error in BAC predictions based on bodyweight is attributable principally to differences in body composition, specifically to the proportion of the body which is fat. A correction could be readily introduced on the basis of body fat estimates. However, accurate fat estimates are not obtainable with presently-known methods except in medical or scientific settings. Since fat can be measured in vivo only by indirect methods, there seems to be little likelihood that simple, accurate measurement methods will be developed.

It is recommended that further research be directed to the development of BAC prediction tables based on the measure "pounds underweight/overweight". In lieu of an accurate method for estimating body fat, it may be feasible to use this measure as a practical approach to improving BAC predictions.

It is recommended that separate tables be constructed for men and women, taking into account the characteristic differences in body composition which result in differing BACs. It is essential that women be aware that for a given amount of alcohol they will reach higher BACs than men. It appears that, on the average, a woman must reduce her alcohol intake to approximately 85% of the amount a man drinks if BACs are to be equal.

REFERENCES

Bharadwaj, H., Verma, S.S., Zachariah, T., Bhatia, M.R., Kishnani, S. and Malhotra, M.S. Estimation of body density and lean body weight from body measurements at high altitude. European Journal of Applied Physiology and Occupational Physiology, 36:141-149, 1977.

Brožek, J. and Keys, A. Evaluation of leanness-fatness in man: A survey of methods. Nutrition Abstracts and Review, 20: 247-256, 1950/51.

Brožek, J., Kihlberg, J.K., Taylor, H.L., and Keys, A. Skinfold distributions in middle-aged American men: A contribution to norms of leanness-fatness. Annals of the New York Academy of Sciences, 110:492-502, 1963.

Clark, D.A., Kay, T.D., Tatsch, R.F. and Theis, C.F. Estimations of body composition by various methods. Aviation, Space and Environmental Medicine, 48(8): 701-704, 1977.

Dixon, W.J. (Series Ed.) and Brown, M.B. (Ed., 1977 Edition) BMDP-77: Biomedical Computer Programs P-Series. University of California Press, Berkeley and Los Angeles, 1977.

Durnin, J.V.G.A. and Rahaman, M.M. The assessment of the amount of fat in the human body from measurements of skinfold thickness. British Journal of Nutrition, 21:681-689, 1967.

Durnin, J.V.G.A. and Womersley, J. Body fat assessed from total body density and its estimation from skinfold thickness: Measurements on 481 men and women aged from 16 to 72 years. British Journal of Nutrition, 32:77-97, 1974.

Katch, F.I. and McArdle, W. Prediction of body density from simple anthropometric measurements in college-age men and women. Human Biology, 45(3):445-454, 1973.

Katch, F.I., McArdle, W.D. and Boylan, B.R. Getting in Shape: An Optimum Approach to Fitness and Weight Control. Boston: Houghton Mifflin Co.,1979.

Keys, A. and Brozek, J. Body fat in adult man. Physiological Reviews, 33(3):245-325, 1953.

Lewis, S., Haskell, W.L., Klein, H., Halpern, J. and Wood, P.D. Prediction of body composition in habitually active middle-aged men. Journal of Applied Physiology, 39(2):221-225, 1975.

Olesen, K. Body composition in normal adults. In: Brozek, J.(Ed.) Human Body Composition: Volume VII: Approaches and Applications. Sumposia of the Society for the Study of Human Biology. Pergamon Press, Symposium Publications Division, 1965

Pascal, L.R., Grossman, M.I., Sloane, H.S., and Frankel, I. Correlations between thickness of skinfolds and body density in 88 soldiers. Human Biology 28:165-176, 1956.

Seltzer, C.C. and Mayer, J. A simple criterion of obesity. Postgraduate Medicine, A101-A107,1965.

Sinning, W.E. Anthropometric estimation of body density and lean body weight in women gymnasts. Medicine and Science in Sports, 8(1):58, 1976.

Wang, W.C. and Kou, D.H. Estimation of body fat in Chinese young men. Aerospace Medicine, 45:307-309, 1974.

Williams, S.R. Nutrition and Diet Therapy. St. Louis: C.V. Mosty Co., 1977.

Wright, H.F. and Wilmore, J.H. Estimation of relative body fat and lean body weight in a United States Marine Corps population. Aerospace Medicine, 45:302-306, 1974.

__________ Indiana Driver Manual, Indiana Bureau of Motor Vehicles, 1974.

APPENDIX I

Methods for Making Body Measurements and Calculating Estimates of Body Fat

There are no direct methods of measuring body fat in vivo. All methods are indirect estimates, and one indirect method can be validated only in terms of other indirect methods. For the purposes of this study, a high degree of precision in estimating body fat is not required; it would be adequate for an individual to be able to determine the percent of total bodyweight that is fat within 5 to 10%.

Two types of body measurements were taken to be used in calculating estimates of body fat. Skinfolds were measured at four different sites, and various body circumferences were measured. The obtained values were then used in conjunction with published tables of fat estimates and in formulae for calculating percent fat. Skinfolds were measured with a Lange Skinfold caliper (mm), and circumferences were measured with a Lufkin cloth tape (in., mm). The sites chosen for the measurements were those that are recommended in the literature as good predictors of body fat.

Skinfolds

Skinfold measurements were first used by Brožek and Keys (1950), and a number of intestigators of body composition have continued during ensuing years to develop and use the methodology. Note, however, that the method requires a caliper of scientific quality and precision. Such instruments usually are available only in scientific laboratories and medical offices and thus the method has very limited applicability for use by the general public.

A skinfold is defined as the thickness of the pinched "fold" of skin plus the attached subcutaneous tissue, but not including the muscle tissue. The measurements were made with subjects standing. A full fold of the skin and subcutaneous tissue was pinched up with the thumb and the forefinger of the left hand at a distance of approximately 1 cm from the site where the caliper was to be placed. The fold was pulled away from the underlying muscle. The Lange caliper was applied to the fold approximately 1 cm below the fingers, so that the pressure on the fold at the point of measurement was exerted by the faces of the caliper and not by the fingers. The handle of the caliper was released to permit the full force of the caliper's arm pressure to be applied, and the dial was read to the nearest 0.5 mm. Caliper application was made at least twice to obtain stable readings. If the folds were extremely thick, dial readings were made three seconds after applying the caliper pressure. If the first two measures were inconsistent, a third one was made.

The sites of the skinfold measurements for all subjects were:

biceps	midway on belly of the biceps muscle with the subject's right arm extended in a natural relaxed position along the side of the body, the skinfold running parallel to length of arm.
triceps	back of subject's arm, upper right, midway between the acromion and olecronon processes, arm hanging freely. The exact midpoint was determined with a measuring tape. Because of gradation of subcutaneous fat in this area, the consistent location of the measurement site is critical to accuracy.
subscapula	site just below the angle of the subject's right scapula with shoulder and arm relaxed. The skinfold was picked up in a line slightly inclined in the natural cleavage of the skin.
suprailiac	measurement was made at a site above the iliac crest in the midaxillary line on the right side.

Although there is substantial literature on body composition, the generality of much of the data which have been published is limited because the studies have examined highly restricted populations. This is illustrated in the following examples of studies:

Investigators	Population Studied
Pascale et al. (1956)	Soldiers
Brožek et al. (1963)	Railroad clerks and switchmen
Katch and McArdle (1973)	College age men and women
Wang and Kou (1974)	Young Chinese men
Lewis et al. (1975)	Physically active men ages 35-67 years
Sinning (1976)	College women gymnasts
Bharadwaj (1977)	Indian soldiers
Clark et al. (1977)	Overweight young men

It would be inappropriate to apply to the general population the norms which were established in these special groups. Fortunately, there are at least three studies which are based on more appropriate samples.

The first is by Seltzer and Mayer (1965) who published a table of triceps skinfold values which they represent as "obesity standards", based on the distribution of triceps skinfolds among Caucasian Americans (Table 1, Appendix I).

In 1967 Durnin and Rahaman reported a study of British adults and adolescents and provided a table relating skinfolds to percent body fat (Table 2, Appendix I). A second study from this group (Durnin and Womersley, 1974) reported the relationship of skinfolds and body fat for 408 men and women ages 16 to 72 years (Table 3, Appendix I). The norms established in these broader-based studies were used to evaluate the skinfold measures taken during this study.

Circumferences

Circumference measurements were made with the subject standing in a relaxed position. The measuring tape was applied tight enough to just avoid indenting the tissue. The circumferences included:

		Measurement made for*
waist	Tape encircled natural waist above the iliac crest.	All subjects
girth	Tape rested on iliac crest coming forward at a downward angle and meeting at the navel.	All subjects
thigh	The upper right thigh circumference was measured just below the buttock	All females
arm	The right forearm was measured with the arm extended straight, palm out in front of the body. The tape was placed around the widest circumference between elbow and wrist.	Females, 17-35 years All males
calf	The right calf was measured at the widest circumference between ankle and knee.	Females, 36 years or older.

buttocks	The subject stood with heels together, and the circumference was measured in the area of maximum protrusion.	Males, 36 years or older.
upper arm	The arm was held straight, palm out and extended in front of body. Measurement was made midway between elbow and wrist.	Males, 17-35 years

* The measurements required for calculations of percent fat differed by both age and sex. Therefore, not all measurements were made for all subjects.

One formula, examined as a method for calculating body fat estimates, uses both skinfolds and circumferences. It was developed by Wright and Wilmore (1974) with a study of 297 Marines. They made nine skinfold, 15 circumference, and nine diameter measurements and used them in a stepwise linear regression to determine the best equation for estimating body fat and lean body weight (LBW). They found that LBW, as confirmed by hydrostatic weighing, could be predicted with R = 0.88 using only two measures in the following equation:

$$LBW = 40.99 + (1.0435 \times Weight) - (0.6734 \times Abdomen\ 2^*)$$

*Abdomen 2 is the girth, i.e., the abdominal circumference measured just above the iliac crests.

Once the LBW has been obtained only simple arithmetic calculations are required to determine pounds of fat and percent fat.

A second method examined was that of Katch, McArdle and Boylan (1979) which they derived from computer analysis of data from " ...carefully conducted experiments on large groups of men and women of all ages ..." (p. 22) Their tables of conversion constants for certain body measures and their formulae can be used to calculate estimated percent body fat by age group and by sex. (The publisher would not permit reproduction of the copyrighted tables in this report).

Estimates of percent body fat, based on skinfolds and circumferences, for the 40 laboratory experiment subjects are tabled in Appendix II.

Method for Calculating Expected BAC

A method for calculating the expected blood alcohol concentration (BAC), taking into account the percent of bodyweight which is water, is described and illustrated with an example in the following:

% BAC = grams alcohol/ml blood
.10% BAC = .0010 g alcohol/ml blood

The percent of bodyweight which is water is:

58% for men (estimate)
49% for women (estimate)

Blood is approximately 80.6% water.

$$\text{BAC} = \frac{\text{total alcohol dose (g)}}{\text{total body water (liter)}} = \frac{\text{g alc}}{.806 \text{ X } 1 \text{ } H_2O}$$

Example:

70 Kg male   Alcohol dose .85 g alcohol/Kg bodyweight

Total alcohol dose = .85 x 70 Kg = 59.50 g alcohol
Total body water = .58 x 70 Kg = 40.60 liters water*

$$\frac{59.50}{40.60} = 1.47 \text{ g alcohol/l} = .00147 \text{ g/ml}$$

Blood = 80.6% water = .806 x.00147 = .00118 g alc/ml blood

= .118% BAC

These calculations assume instantaneous distribution of the alcohol in the body.

Assuming a BAC decrease of .017%/hour, the predicted BAC one hour after the start of drinking will be .118% - .017% = .101%.

---

* 1 liter water weight 1 Kg

TABLE 1

Obesity Standards in Caucasian Americans*

AGE (Yrs)	MINIMUM TRICEPS SKINFOLD THICKNESS INDICATING OBESITY (Millimeters)	
	Males	Females
5	12	14
6	12	15
7	13	16
8	14	17
9	15	18
10	16	20
11	17	21
12	18	22
13	18	23
14	17	23
15	16	24
16	15	25
17	14	26
18	15	27
19	15	27
20	16	28
21	17	28
22	18	28
23	18	28
24	19	28
25	20	29
26	20	29
27	21	29
28	22	29
29	22	29
30-50	23	30

*taken from: Seltzer, Carl C. and Mayer, Jean. A Simple Criterion for Obesity. Postgraduate Medicine, 38: A101-A107, 1965.

TABLE 2

Percentages of Fat Corresponding to the Total Value of Skinfolds at Four Sites (Biceps, Triceps, Subscapular and Suprailiac)*

(Rounding off in the percentages of fat accounts for the differences between adjoining values not being uniform)

TOTAL SKINFOLD (mm)	FAT (% body-weight)			
	MEN	WOMEN	BOYS	GIRLS
15	5.5	-	9.0	12.5
20	9.0	15.5	12.5	16.0
25	11.5	18.5	15.5	19.0
30	13.5	21.0	17.5	21.5
35	15.5	23.0	19.5	23.5
40	17.0	24.5	21.5	25.0
45	18.5	26.0	23.0	27.0
50	20.0	27.5	24.0	28.5
55	21.0	29.0	25.5	29.5
60	22.0	30.0	26.5	30.5
65	23.0	31.0	27.5	32.0
70	24.0	32.5	28.5	33.0
75	25.0	33.5	29.5	34.0
80	26.0	34.0	-	-
85	26.5	35.0	-	-
90	27.5	36.0	-	-
95	28.0	36.5	-	-

*taken from: Durnin, J.V.G.A. and Rahaman, M.M. The assessment of the amount of fat in the human body from measurements of skinfold thickness. British Journal of Nutrition, 21: 681-689, 1967.

TABLE 3

The Equivalent Fat Content, as a Percentage of Body-Weight, for a Range of Values for the Sum of Four Skinfolds (Biceps, Triceps, Subscapular and Suprailiac) of Males and Females of Different Ages

SKINFOLDS (mm)	MALES (age in yrs) 17-29	30-39	40-49	50+	FEMALES (age in yrs) 16-29	30-39	40-49	50+
15	4.8	-	-	-	10.5	-	-	-
20	8.1	12.2	12.2	12.6	14.1	17.0	19.8	21.4
25	10.5	14.2	15.0	15.6	16.8	19.4	22.2	24.0
30	12.9	16.2	17.7	18.6	19.5	21.8	24.5	26.6
35	14.7	17.7	19.6	20.8	21.5	23.7	26.4	28.5
40	16.4	19.2	21.4	22.9	23.4	25.5	28.2	30.3
45	17.7	20.4	23.0	24.7	25.0	26.9	29.6	31.9
50	19.0	21.5	24.6	26.5	26.5	28.2	31.0	33.4
55	20.1	22.5	25.9	27.9	27.8	29.4	32.1	34.6
60	21.2	23.5	27.1	29.2	29.1	30.6	33.2	35.7
65	22.2	24.3	28.2	30.4	30.2	31.6	34.1	36.7
70	23.1	25.1	29.3	31.6	31.2	32.5	35.0	37.7
75	24.0	25.9	30.3	32.7	32.2	33.4	35.9	38.7
80	24.8	26.6	31.2	33.8	33.1	34.3	36.7	39.6
85	25.5	27.2	32.1	34.8	34.0	35.1	37.5	40.4
90	26.2	27.8	33.0	35.8	34.8	35.8	38.3	41.2
95	26.9	28.4	33.7	36.6	35.6	36.5	39.0	41.9
100	27.6	29.0	34.4	37.4	36.4	37.2	39.7	42.6
105	28.2	29.6	35.1	38.2	37.1	37.9	40.4	43.3
110	28.8	30.1	35.8	39.0	37.8	38.6	41.0	43.9
115	29.4	30.6	36.4	39.7	38.4	39.1	41.5	44.5
120	30.0	31.1	37.0	40.4	39.0	39.6	42.0	45.1
125	30.5	31.5	37.6	41.1	39.6	40.1	42.5	45.7
130	31.0	31.9	38.2	41.8	40.2	40.6	43.0	46.2
135	31.5	32.3	38.7	42.4	40.8	41.1	43.5	46.7
140	32.0	32.7	39.2	43.0	41.3	41.6	44.0	47.2
145	32.5	33.1	39.7	43.6	41.8	42.1	44.5	47.7
150	32.9	33.5	40.2	44.1	42.3	42.6	45.0	48.2
155	33.3	33.9	40.7	44.6	42.8	43.1	45.4	48.7
160	33.7	34.3	41.2	45.1	43.3	43.6	45.8	49.2
165	34.1	34.6	41.6	45.6	43.7	44.0	46.2	49.6
170	34.5	34.8	42.0	46.1	44.1	44.4	46.6	50.0
175	34.9	-	-	-	-	44.8	47.0	50.4
180	35.3	-	-	-	-	45.2	47.4	50.8
185	35.6	-	-	-	-	45.6	47.8	51.2
190	35.9	-	-	-	-	45.9	48.2	51.6
195	-	-	-	-	-	46.2	48.5	52.0
200	-	-	-	-	-	46.5	48.8	52.4
205	-	-	-	-	-	-	49.1	52.7
210	-	-	-	-	-	-	49.4	53.0

*taken from: Durnin, J.V.G.A., and Womersley, J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. British Journal of Nutrition, 32: 77-97, 1974.

APPENDIX II

Tables and Figures

Figure 1: Height-Weight Distribution for 40 Laboratory Experiment Subjects

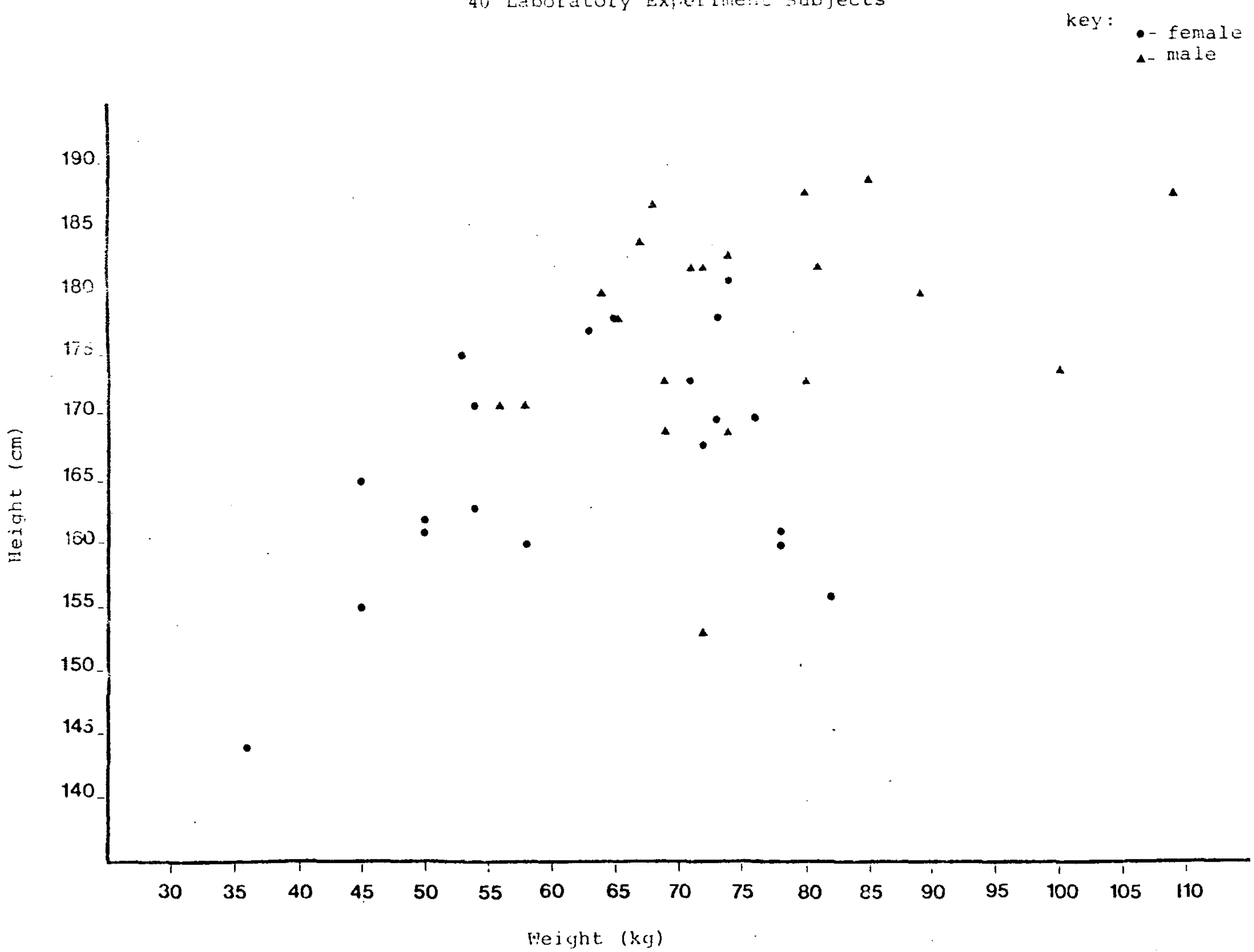


TABLE 1

Summary of Body Measures
Male Subjects

SUBJECT NO.	AGE	HEIGHT (cm)	WEIGHT (kg)	SKINFOLD MEASURES (SF) (in mm)				
				BICEPS	TRICEPS	SUPRA-ILIAC	SUB-SCAPULA	TOTAL SF
20	31	179.71	89.09	5.00	11.75	26.25	16.25	59.25
21	23	153.04	71.59	9.00	18.50	26.00	26.50	80.00
22	21	183.52	67.27	4.00	4.00	8.50	11.25	27.75
23	25	171.45	56.36	3.00	6.75	8.50	8.00	26.25
24	25	181.61	81.36	5.00	7.75	17.75	11.75	42.25
25	28	173.99	99.55	8.00	11.50	39.50	26.50	85.50
26	29	187.96	108.64	4.00	12.75	37.50	26.50	80.75
27	28	188.59	84.55	5.00	10.75	19.50	12.75	48.00
28	21	171.45	58.18	2.75	4.00	5.50	6.75	19.00
29	26	173.36	79.55	5.00	11.50	17.00	14.50	48.00
30	22	186.69	67.73	4.00	8.25	21.75	12.50	46.50
31	33	187.96	79.55	4.50	11.00	19.67	10.50	45.67
32	29	181.61	71.36	5.75	13.00	14.00	10.50	43.25
33	34	180.34	63.64	3.00	4.75	11.00	9.00	27.75
34	26	178.44	65.45	3.00	8.00	16.00	9.00	36.00
35	39	168.91	74.32	7.00	8.50	22.75	10.50	48.75
36	23	168.91	69.09	5.25	10.00	12.25	15.25	42.75
37	31	172.72	69.32	4.50	10.00	17.50	11.00	43.00
38	25	181.61	71.82	3.00	7.00	17.75	13.00	40.75
39	26	182.88	73.64	7.00	6.25	18.25	14.50	46.00
$\bar{X}$	27.25	177.74	75.10	4.89	9.30	18.85	13.83	46.86
σ	4.67	8.66	12.92	1.75	3.52	8.71	5.97	17.85

TABLE 1

Summary of Body Measures
Male Subjects

SUBJECT NO.		BODY CIRCUMFERENCES (cm) ABDO 1 (waist)	RT/UA	RIGHT FOREARM	ABDO 2
20		96.85	30.48	28.73	98.00
21		92.41	31.75	27.64	93.50
22		73.81	28.09	26.67	78.00
23		76.84	24.13	23.50	77.50
24		87.15	33.66	28.91	90.00
25		100.33	35.08	30.63	101.00
26		111.13	38.43	29.85	109.00
27		85.73	30.81	27.94	90.00
28		66.04	26.67	25.73	67.00
29		85.57	32.23	29.54	91.00
30		72.57	25.40	26.37	76.00
31		83.19	28.58	27.64	85.50
32		79.07	29.85	26.19	79.50
33		74.93	27.94	27.00	76.50
34		73.76	27.94	24.77	76.00
35		89.74	27.94	27.94	91.00
36		81.28	31.12	27.46	82.00
37		82.55	30.48	26.37	86.00
38		78.44	27.94	25.88	81.00
39		85.73	29.21	27.46	88.00
	$\overline{X}$	83.86	29.89	27.31	85.83
	σ	10.64	3.33	1.73	10.03

TABLE 1

Summary of Body Measures
Female Subjects

SUBJECT NO.		AGE	HEIGHT (cm)	WEIGHT (kg)	SKINFOLD MEASURES (SF) (in mm) BICEPS	TRICEPS	SUPRA-ILIAC	SUB-SCAPULA	TOTAL SF
40		28	167.64	72.27	6.50	11.50	12.67	11.50	42.17
41		32	172.72	70.91	7.50	10.00	10.50	11.00	39.00
42		25	171.45	53.64	6.50	2.50	8.50	8.00	25.50
43		23	165.10	44.55	4.00	11.50	8.50	7.50	31.50
44		21	170.18	76.14	8.50	10.50	11.50	11.50	42.00
45		25	177.80	64.55	5.50	10.50	9.00	11.00	36.00
46		35	177.80	72.73	11.50	18.50	15.00	13.50	58.50
47		26	161.93	49.55	4.50	9.50	8.00	7.00	29.00
48		23	160.02	77.73	14.50	20.50	21.50	27.50	84.00
49		28	154.94	45.45	4.00	7.00	8.00	9.00	28.00
50		27	161.29	77.73	10.00	14.50	15.50	16.00	56.00
51		30	165.10	57.50	6.50	12.50	11.00	6.50	36.50
52		25	180.98	73.64	5.00	10.50	8.50	11.00	35.00
53		23	162.56	53.86	7.00	11.50	8.50	10.00	37.00
54		46	161.29	50.45	2.50	8.50	9.50	6.50	27.00
55		28	175.26	52.73	4.00	13.00	8.00	9.00	34.00
56		30	176.53	62.73	5.00	9.50	9.50	9.50	33.50
57		30	143.51	36.36	2.00	4.50	6.00	5.00	17.50
58		29	156.21	82.27	15.00	24.50	30.25	24.00	93.75
59		30	170.18	72.73	5.00	9.00	10.00	10.50	34.50
	$\bar{X}$	28.20	166.62	62.38	6.75	11.50	11.50	11.28	41.02
	σ	5.43	9.29	13.43	3.59	5.08	5.63	5.60	18.93

TABLE 1

Summary of Body Measures
Female Subjects

SUBJECT NO.		BODY CIRCUMFERENCES (cm) ABDO 1 (waist)	RT/UA	RIGHT FOREARM	ABDO 2
40		77.47	69.22	24.13	79.00
41		73.66	60.96	25.40	80.00
42		62.23	54.31	21.59	66.00
43		62.87	44.45	20.32	63.75
44		82.55	66.04	23.50	94.00
45		70.18	57.15	23.50	77.00
46		81.28	60.33	25.73	81.50
47		66.68	52.07	21.59	68.75
48		85.09	71.12	26.67	85.00
49		66.04	50.80	19.05	68.50
50		87.63	63.50	26.67	85.00
51		67.31	56.52	22.56	73.00
52		69.85	64.14	24.13	74.00
53		62.23	52.71	23.50	70.00
54		57.79	47.63	18.75	60.00
55		64.14	53.98	22.23	66.25
56		70.49	49.53	21.59	69.00
57		53.98	43.18	21.92	58.50
58		107.95	69.22	27.94	118.00
59		73.03	64.14	25.10	76.00
	$\overline{X}$	72.12	57.55	23.29	75.91
	σ	12.35	8.38	2.51	13.64

TABLE 2

Summary of Body Composition Calculations and
Peak Blood Alcohol Concentration - Male Subjects

				ESTIMATES (WRIGHT & WILMORE)				ESTIMATES (KATCH, et al.)		
SUBJECT NO.	AGE	PEAK BAC(%)	DESIRABLE WEIGHT(KG)*	% FAT	FAT WEIGHT	LEAN BODY WEIGHT	IDEAL WEIGHT	% FAT	FAT WEIGHT	LEAN BODY WEIGHT
20	31	.084	71.25	23.70	21.13	67.96	77.67	22.28	20.33	68.76
21	23	.094	53.98	26.30	18.86	52.74	60.27	24.74	17.71	53.89
22	21	.077	74.20	12.80	8.61	58.66	67.04	11.86	7.98	59.29
23	25	.073	61.36	15.50	8.75	47.61	54.41	14.42	8.13	48.23
24	25	.085	77.95	19.80	16.08	65.28	74.61	18.10	14.73	66.63
25	28	.079	72.27	22.80	22.69	76.86	87.84	27.26	27.14	72.41
26	29	.104	83.64	25.50	27.68	80.96	92.53	39.38	42.78	65.86
27	28	.070	84.20	18.85	15.94	68.61	78.41	19.24	16.26	68.29
28	21	.062	61.36	2.74	1.60	56.58	64.66	7.81	4.54	53.64
29	26	.097	66.36	21.40	16.78	61.77	70.59	17.85	14.03	64.61
30	22	.079	76.82	10.70	7.24	60.49	69.13	11.63	7.88	59.85
31	33	.090	73.18	16.50	13.13	66.42	75.91	15.36	12.22	67.33
32	29	.079	72.73	13.20	9.44	61.92	70.77	18.15	12.95	58.41
33	34	.074	71.82	12.20	7.76	55.88	63.86	11.53	7.34	56.30
34	26	.085	70.11	11.20	7.34	58.11	66.41	15.67	10.26	55.13
35	39	.096	67.95	22.95	17.06	57.26	65.44	24.46	18.18	56.14
36	23	.071	63.18	16.20	11.22	57.87	66.14	18.42	12.73	56.36
37	31	.077	65.91	20.10	13.91	55.41	63.33	20.53	14.23	55.09
38	25	.074	72.73	14.50	10.43	61.39	70.16	16.39	11.77	60.05
39	26	.080	73.64	20.50	15.07	58.57	66.94	17.94	13.21	60.43
$\overline{X}$	27yrs3mos	.082	70.73	17.37	13.59	61.52	70.31	18.68	14.72	60.34
σ	4yrs8mos	.010	7.40	5.91	6.37	7.84	8.96	6.90	8.38	6.32

*Derived from Metropolitan Life Insurance Co. table of height and weight (for subjects heights and weights see Table 1)

TABLE 2

Summary of Body Composition Calculations
and Peak Blood Alcohol Concentration - Female Subjects

SUBJECT NO.	AGE	PEAK BAC(%)	** DESIRABLE WEIGHT(KG)	ESTIMATES (WRIGHT & WILMORE) % FAT	FAT WEIGHT	LEAN BODY WEIGHT	IDEAL WEIGHT	ESTIMATES (KATCH, et al.) % FAT	FAT WEIGHT	LEAN BODY WEIGHT
40	28	.106	57.73	12.53	9.06	63.21	72.27	36.91	26.69	45.61
41	32	.111	66.36	13.82	9.80	61.11	69.84	26.00	18.44	52.47
42	25	.087	56.82	2.09	1.12	52.52	60.02	20.98	11.25	42.39
43	23	.100	52.27	*	*	*	*	15.42	6.87	37.68
44	21	.080	59.55	24.95	19.00	57.14	65.30	38.07	28.99	47.15
45	25	.107	65.45	12.47	8.05	56.50	64.57	24.27	15.67	48.88
46	35	.097	70.00	14.75	10.73	62.00	70.86	28.95	21.06	51.67
47	26	.080	50.57	6.36	3.15	46.40	53.05	21.50	10.65	38.90
48	23	.117	52.73	16.56	12.87	64.86	74.13	38.18	29.68	48.05
49	28	.096	46.82	6.95	3.16	42.29	48.33	24.44	11.11	34.34
50	27	.104	53.64	20.88	16.23	61.50	70.29	33.27	25.71	51.56
51	30	.092	55.91	9.86	5.67	51.83	59.23	23.86	13.72	43.78
52	25	.106	72.73	7.66	5.64	68.00	77.71	28.74	21.16	52.48
53	23	.099	54.55	7.07	3.81	50.05	57.20	16.45	8.86	45.00
54	46	.089	52.51	*	*	*	*	21.14	10.67	39.78
55	28	.100	59.55	2.52	1.33	51.40	58.74	20.65	10.89	41.84
56	30	.101	64.55	4.38	2.75	59.98	68.55	21.43	13.44	49.29
57	30	.077	41.82	*	*	*	*	7.00	2.55	33.81
58	29	.106	55.23	42.41	34.89	47.38	54.15	46.49	38.25	44.02
59	30	.093	64.55	9.65	7.02	65.71	75.10	28.79	20.94	51.79
X̄	28yrs2mos	.097	57.67	12.64	9.08	56.58	64.66	26.13	17.33	45.02
σ	5yrs2mos	.011	7.79	9.85	8.38	7.56	8.64	9.18	9.07	5.94

*calculations for these subjects rendered values to the zero order
**derived from Metropolitan Life Insurance Co. table of height/weight (for subject heights and weights see Table 1)

TABLE 3

Comparison: Triceps Measurements and Obesity Standard*
Male Subjects

SUBJECT NO.	TRICEPS SKINFOLD (mm)	OBESITY STANDARD* (triceps, mm)	DIFFERENCE (triceps minus standard)
20	29.85	23	6.85
21	46.99	18	28.99
22	10.16	17	-6.84
23	17.15	20	-2.85
24	19.69	20	-0.31
25	29.21	22	7.21
26	32.39	22	10.39
27	27.31	22	5.31
28	10.16	11	-6.84
29	29.21	20	9.21
30	22.23	18	4.23
31	27.94	23	4.94
32	33.02	22	11.02
33	10.80	23	-12.20
34	20.32	20	0.32
35	21.59	23	-1.41
36	25.40	18	7.40
37	25.40	23	2.40
38	17.78	20	-2.22
39	15.88	20	-4.12

*Seltzer and Mayer (1965). See Table 1, Appendix 1.

TABLE 3

Comparison: Triceps Measurements and Obesity Standard*
Female Subjects

SUBJECT NO.	TRICEPS SKINFOLD (mm)	OBESITY STANDARD* (triceps,mm)	DIFFERENCE (triceps minus standard)
40	29.21	29	0.21
41	27.54	30	-2.46
42	6.35	29	-22.65
43	29.21	28	1.21
44	26.67	28	-1.33
45	26.67	29	-2.33
46	46.99	30	16.99
47	24.13	29	4.87
48	52.07	28	24.07
49	17.78	29	-11.22
50	36.83	29	7.83
51	31.75	30	1.75
52	26.67	29	-2.33
53	29.21	28	1.21
54	21.59	30	-8.41
55	33.02	29	4.02
56	24.13	30	-5.87
57	11.43	30	-18.57
58	62.23	29	33.23
59	22.86	30	-7.14

*Seltzer and Mayer (1965). See Table 1, Appendix 1.

TABLE 4

Four Skinfolds (Total mm) and Estimates of Body Fat by Two Methods
Male Subjects

SUBJECT NO.	PEAK BAC	SKINFOLDS TOTAL (mm)	% FAT DURNIN & RAHAMAN (1967)	% FAT DURNIN & WOMERSLEY (1974)
20	.084	59.25	21.85	23.35
21	.094	80.00	26.00	24.80
22	.077	27.75	12.60	11.82
23	.073	26.25	12.00	11.10
24	.085	42.25	17.68	16.99
25	.079	85.50	26.60	25.57
26	.104	80.75	26.08	24.91
27	.070	48.00	19.40	18.48
28	.062	19.00	8.30	7.44
29	.097	48.00	19.40	18.48
30	.079	47.50	18.95	18.09
31	.090	45.67	18.70	20.54
32	.079	43.25	17.98	17.25
33	.074	27.75	12.60	15.30
34	.085	36.00	15.80	15.04
35	.096	48.75	19.63	21.23
36	.071	42.75	17.83	17.12
37	.077	43.00	17.90	19.92
38	.074	40.75	17.23	16.60
39	.080	46.00	18.80	17.96

TABLE 6

Data Summary for 40 Subjects
$Time_0$ BAC, Bodyweight, and Pounds Underweight or Overweight

FEMALE SUBJECTS				MALE SUBJECTS			
SUBJECT NO.	$TIME_0$ BAC	WEIGHT	POUNDS OVER/UNDER	SUBJECT NO.	$TIME_0$ BAC	WEIGHT	POUNDS OVER/UNDER
40	.122%	159	27.5	20	.107%	196	34.0
41	.126	156	7.5	21	.114	157.5	36.5
42	.100	118	-8.5	22	.095	148	-18.5
43	.112	98	-18.5	23	.095	124	-12.5
44	.092	167.5	36.0	24	.108	179	5.0
45	.124	142	-5.5	25	.082	219	58.5
46	.124	160	12.5	26	.118	239	50.5
47	.099	109	-6.0	27	.094	186	-2.5
48	.136	171	53.5	28	.084	128	-8.5
49	.129	100	-6.0	29	.118	175	26.0
50	.128	170	50.5	30	.098	149	-22.0
51	.111	126.5	8.0	31	.115	175	9.5
52	.122	162	-1.0	32	.100	157	-5.0
53	.115	118.5	5.5	33	.093	140	-22.0
54	.105	111	-1.0	34	.094	144	-13.5
55	.134	116	-19.0	35	.108	163.5	23.0
56	.118	138	-5.5	36	.088	152	11.5
57	.100	80	-19.0	37	.104	152.5	3.5
58	.132	181	68.0	38	.092	158	-4.0
59	.106	160	24.5	39	.110	162	-4.5
$\overline{X}$	.117			$\overline{X}$	.101		
σ	.013			σ	.011		

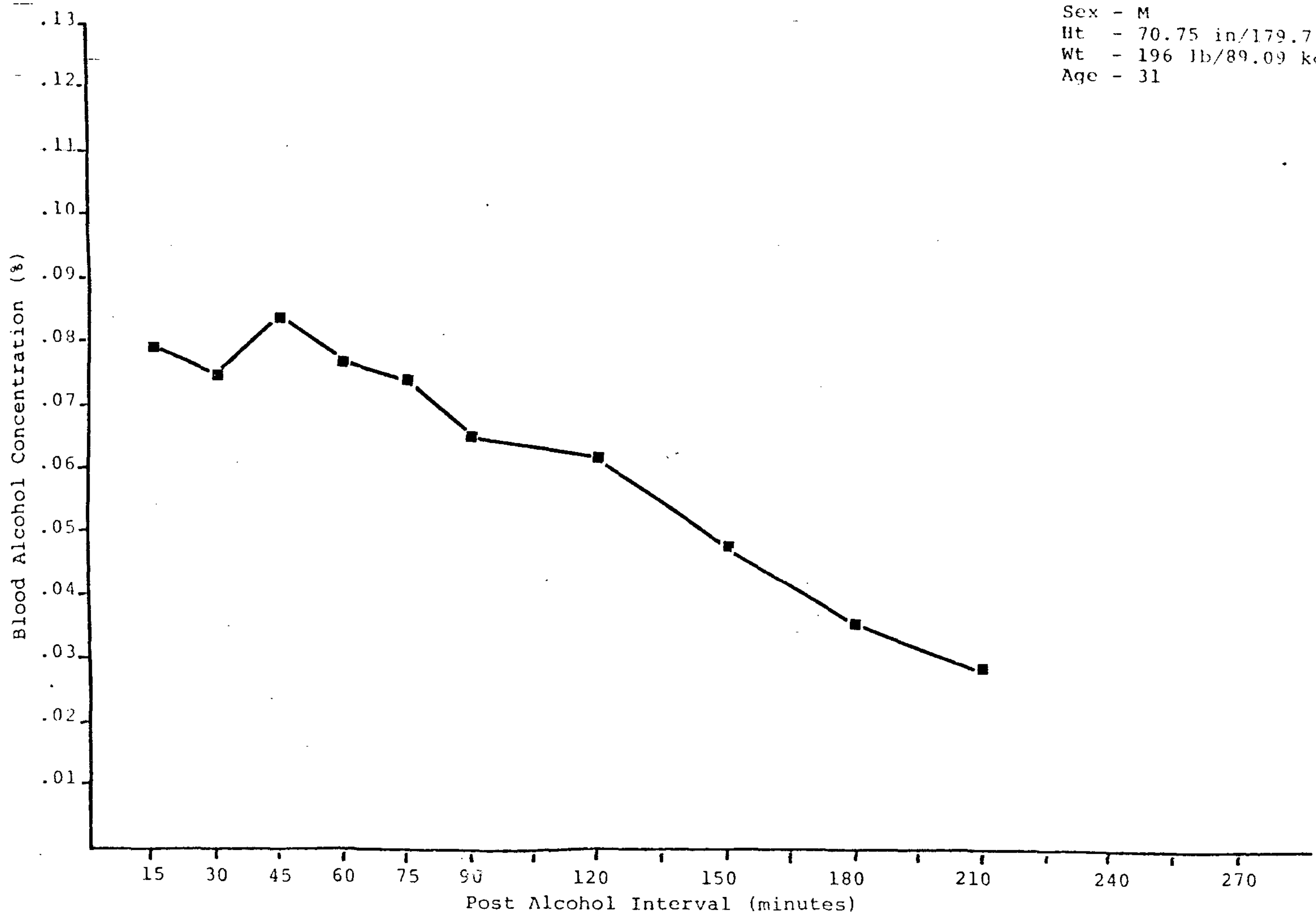
APPENDIX III

Graphs of BAC Curves
for
Individual Subjects

Body Fat - BAC
Laboratory Experiment

S# - 20

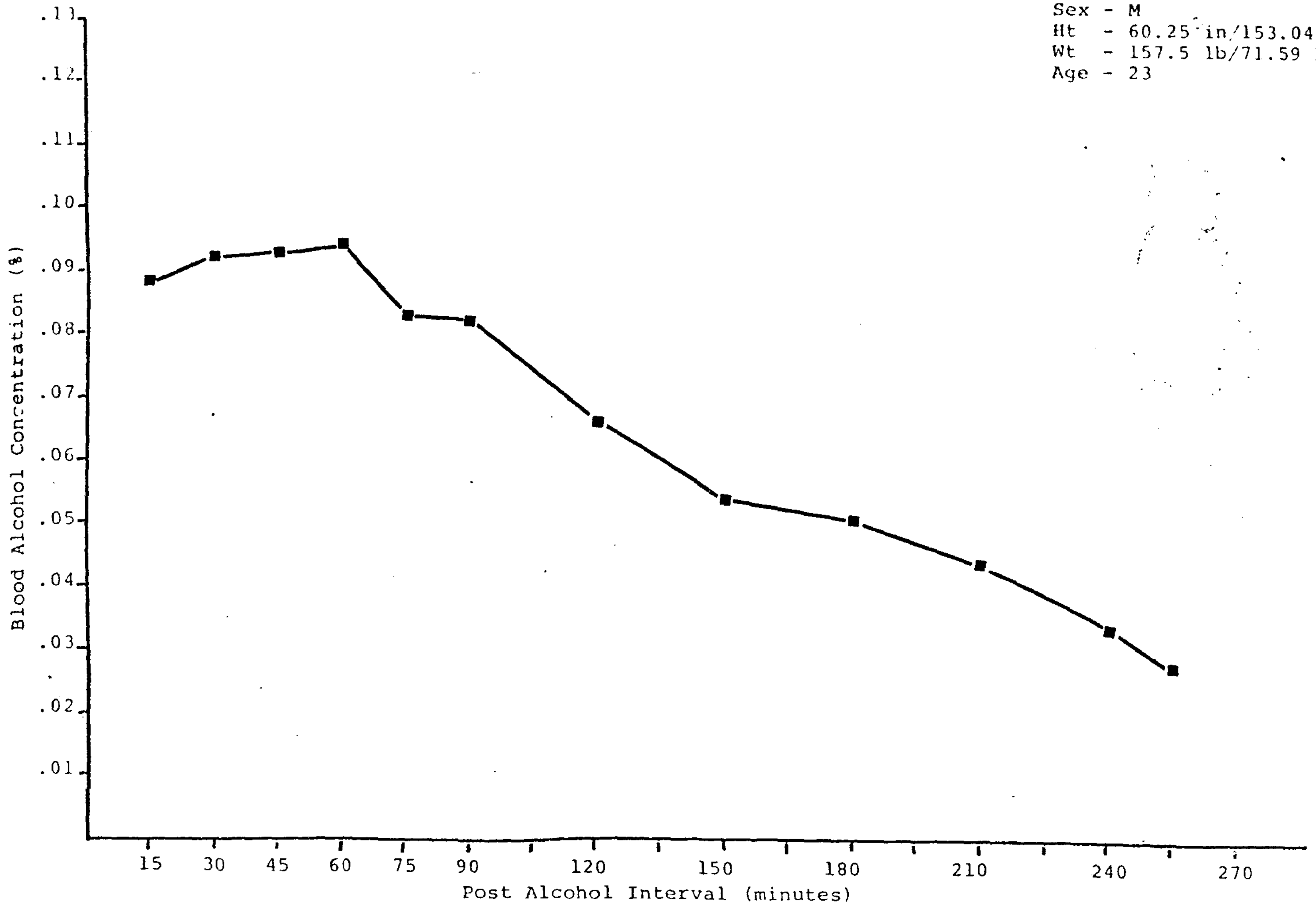
Sex - M
Ht - 70.75 in/179.71cm
Wt - 196 lb/89.09 kg
Age - 31



Body Fat - BAC
Laboratory Experiment

S# - 21

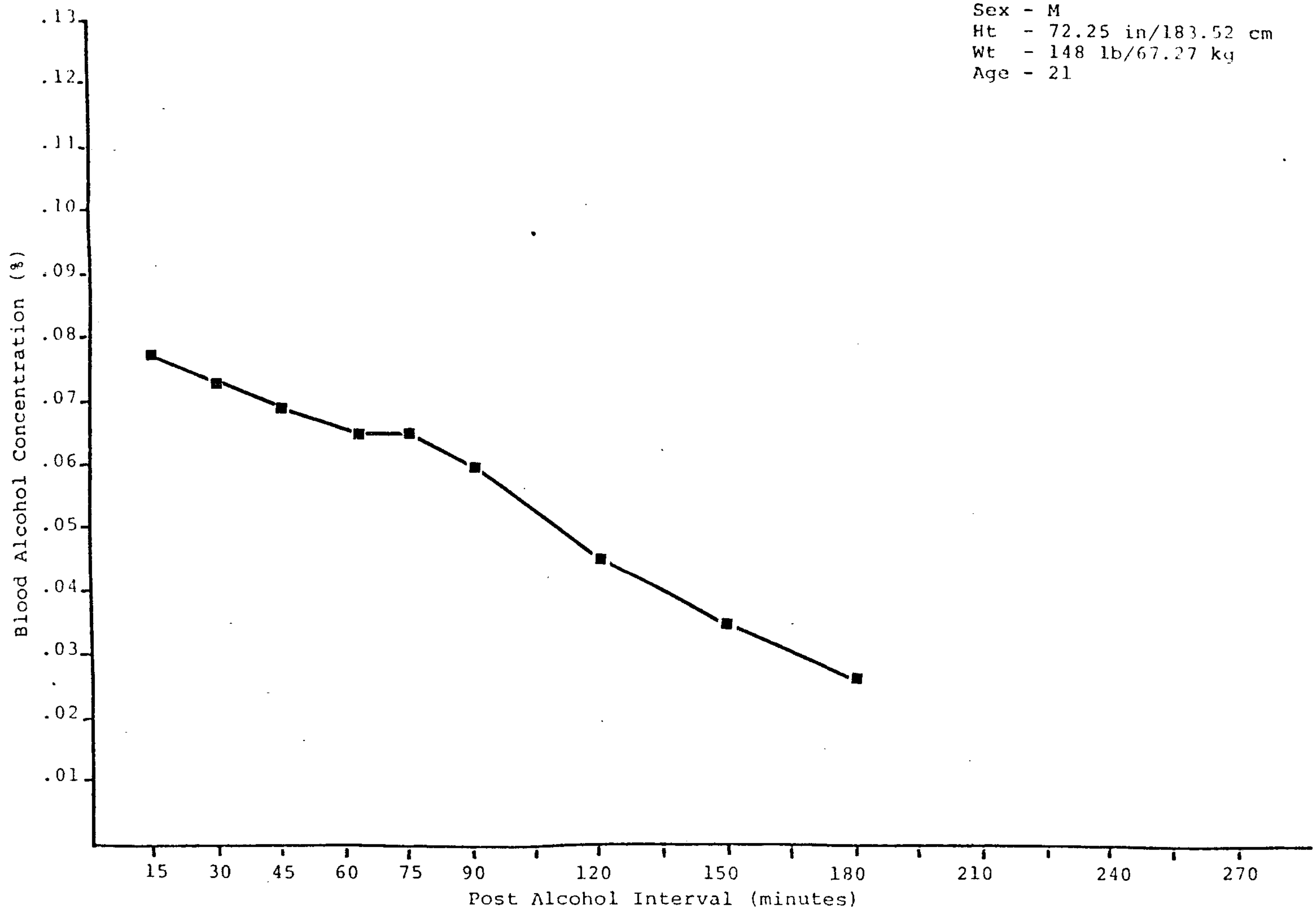
Sex - M
Ht - 60.25 in/153.04 cm
Wt - 157.5 lb/71.59 kg
Age - 23



Body Fat - BAC
Laboratory Experiment

S# - 22

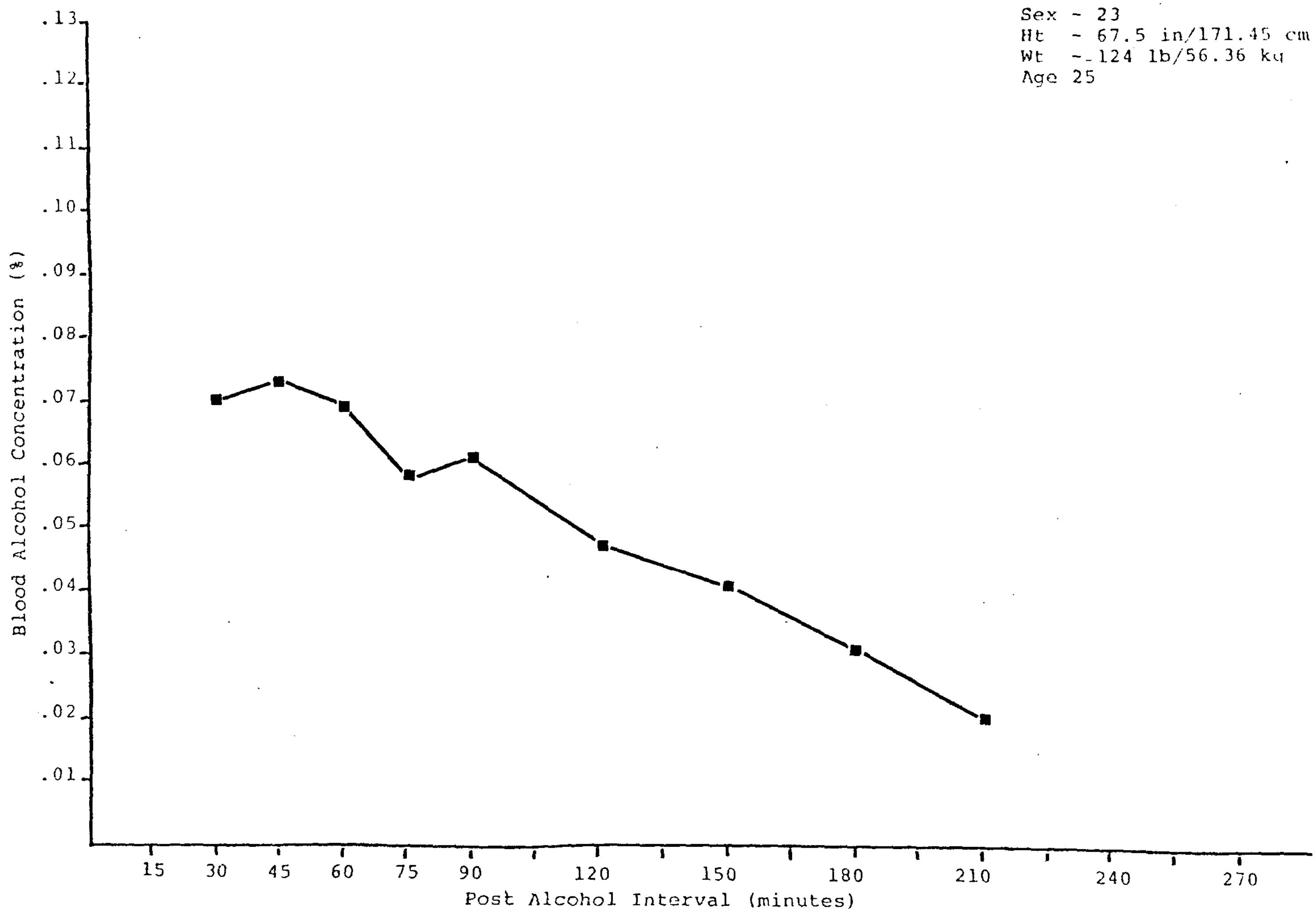
Sex - M
Ht - 72.25 in/183.52 cm
Wt - 148 lb/67.27 kg
Age - 21



Body Fat - BAC
Laboratory Experiment

S# - 23

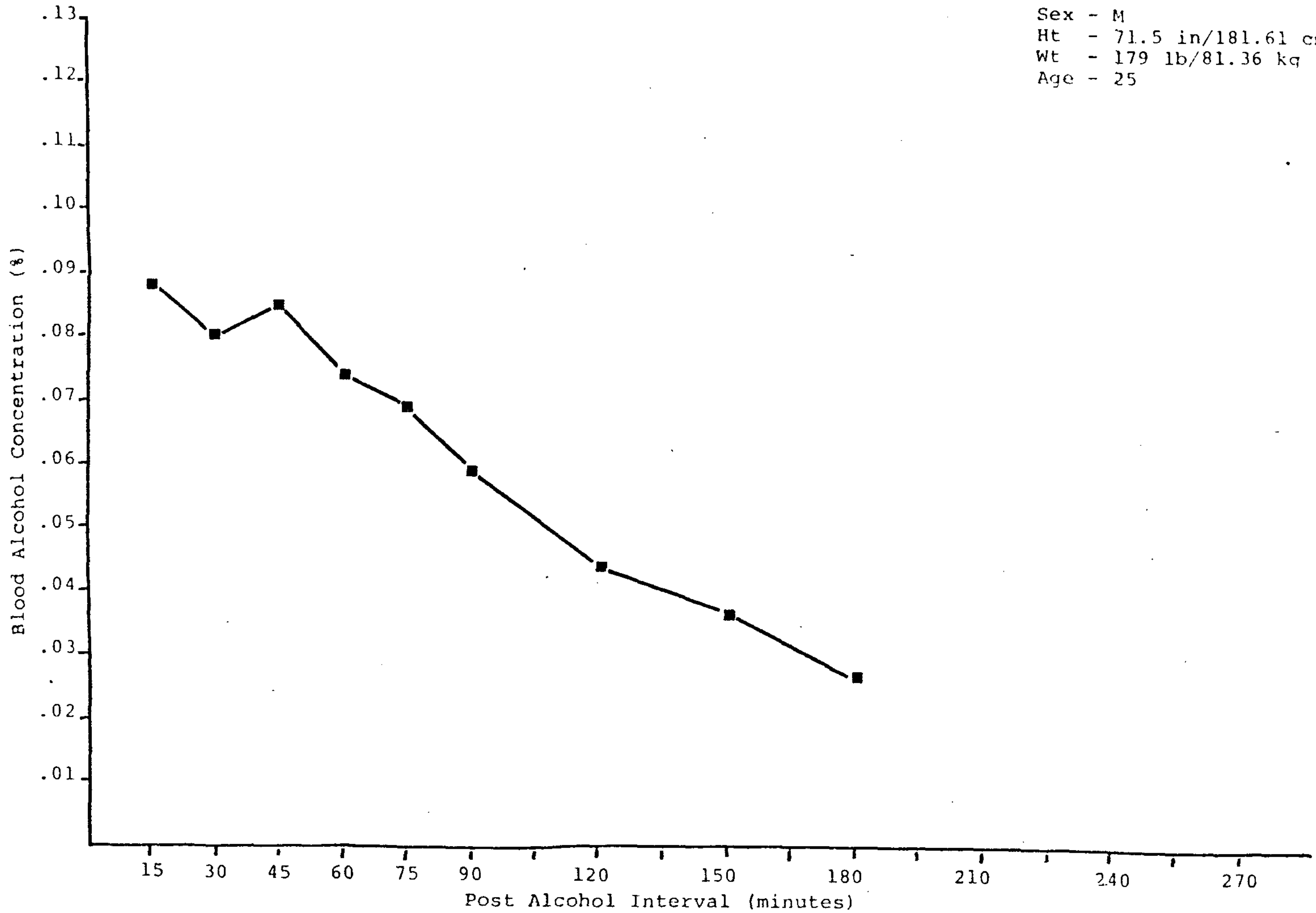
Sex - 23
Ht - 67.5 in/171.45 cm
Wt - 124 lb/56.36 kg
Age 25



Body Fat - BAC
Laboratory Experiment

S# - 24

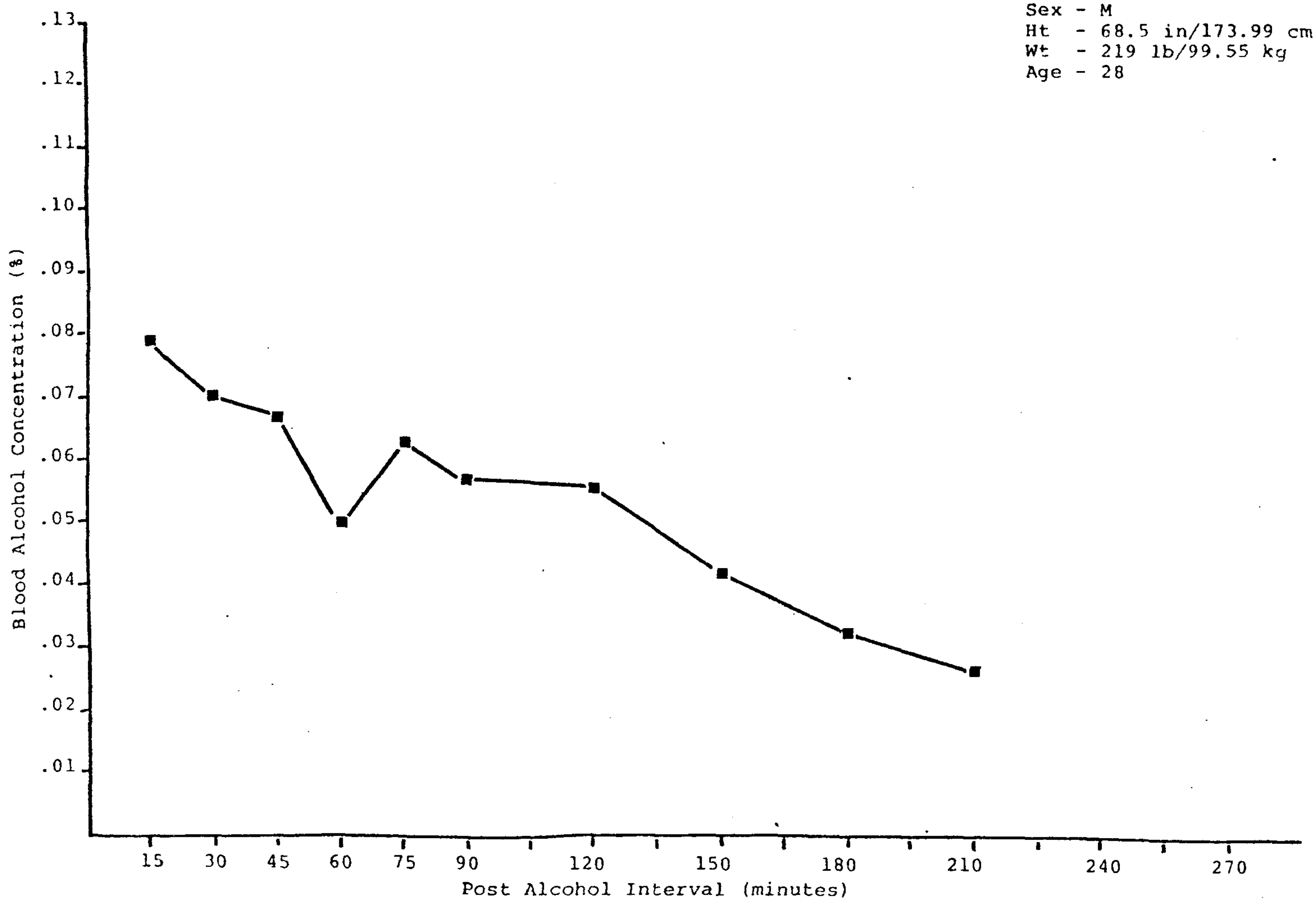
Sex - M
Ht - 71.5 in/181.61 cm
Wt - 179 lb/81.36 kg
Age - 25



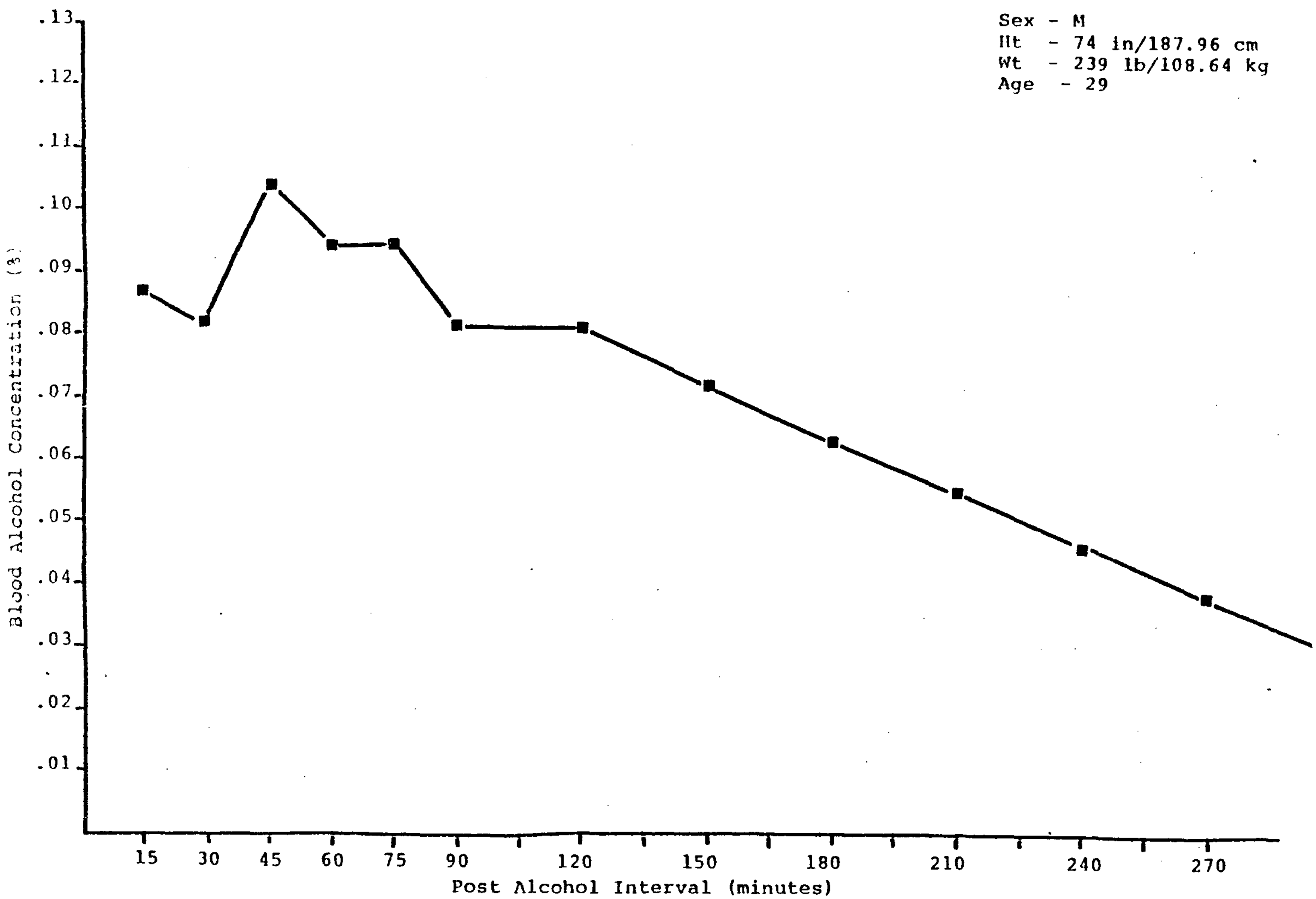
Body Fat - BAC
Laboratory Experiment

S# - 25

Sex - M
Ht - 68.5 in/173.99 cm
Wt - 219 lb/99.55 kg
Age - 28



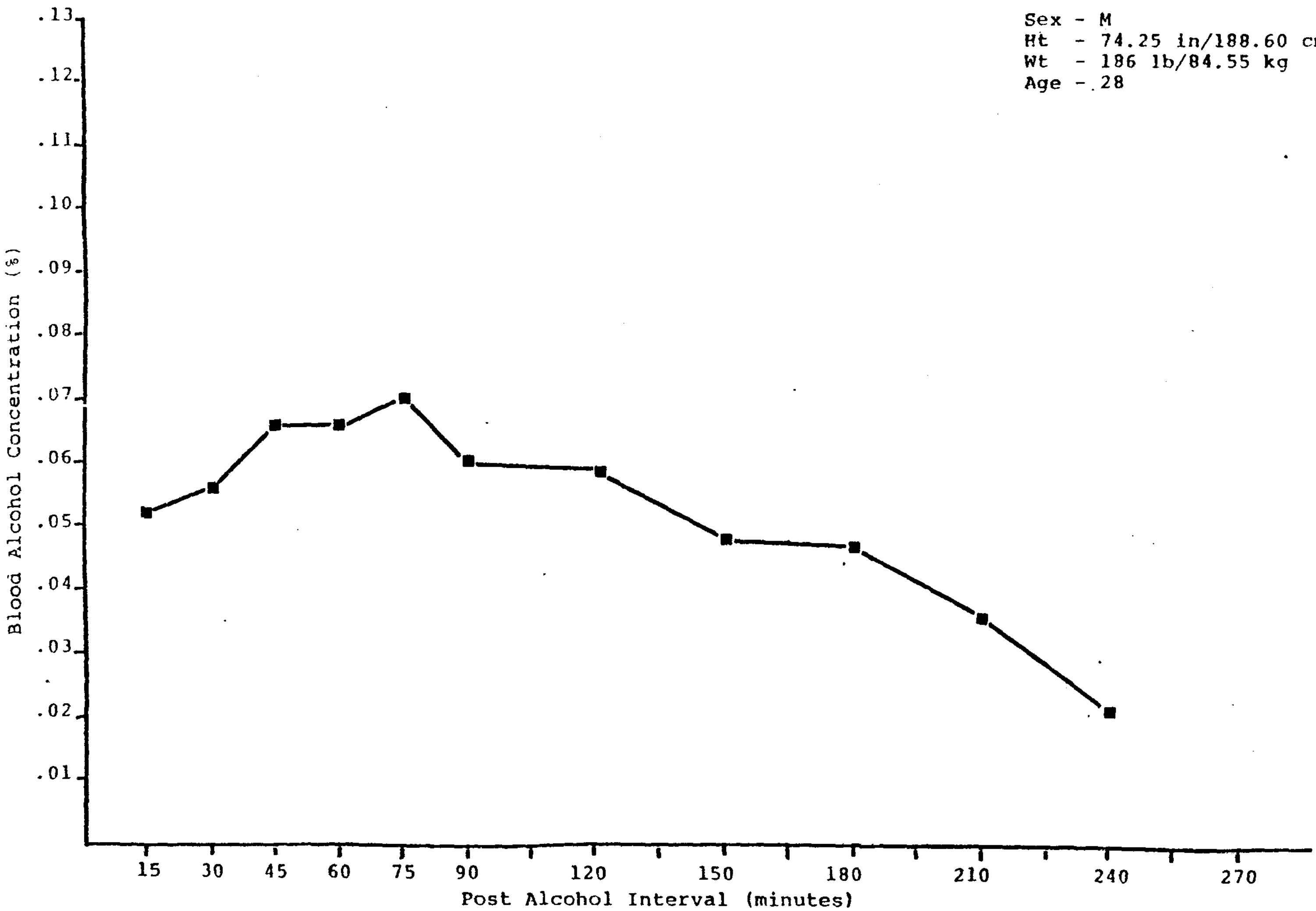
Body Fat - BAC
Laboratory Experiment



Body Fat - BAC
Laboratory Experiment

S# - 27

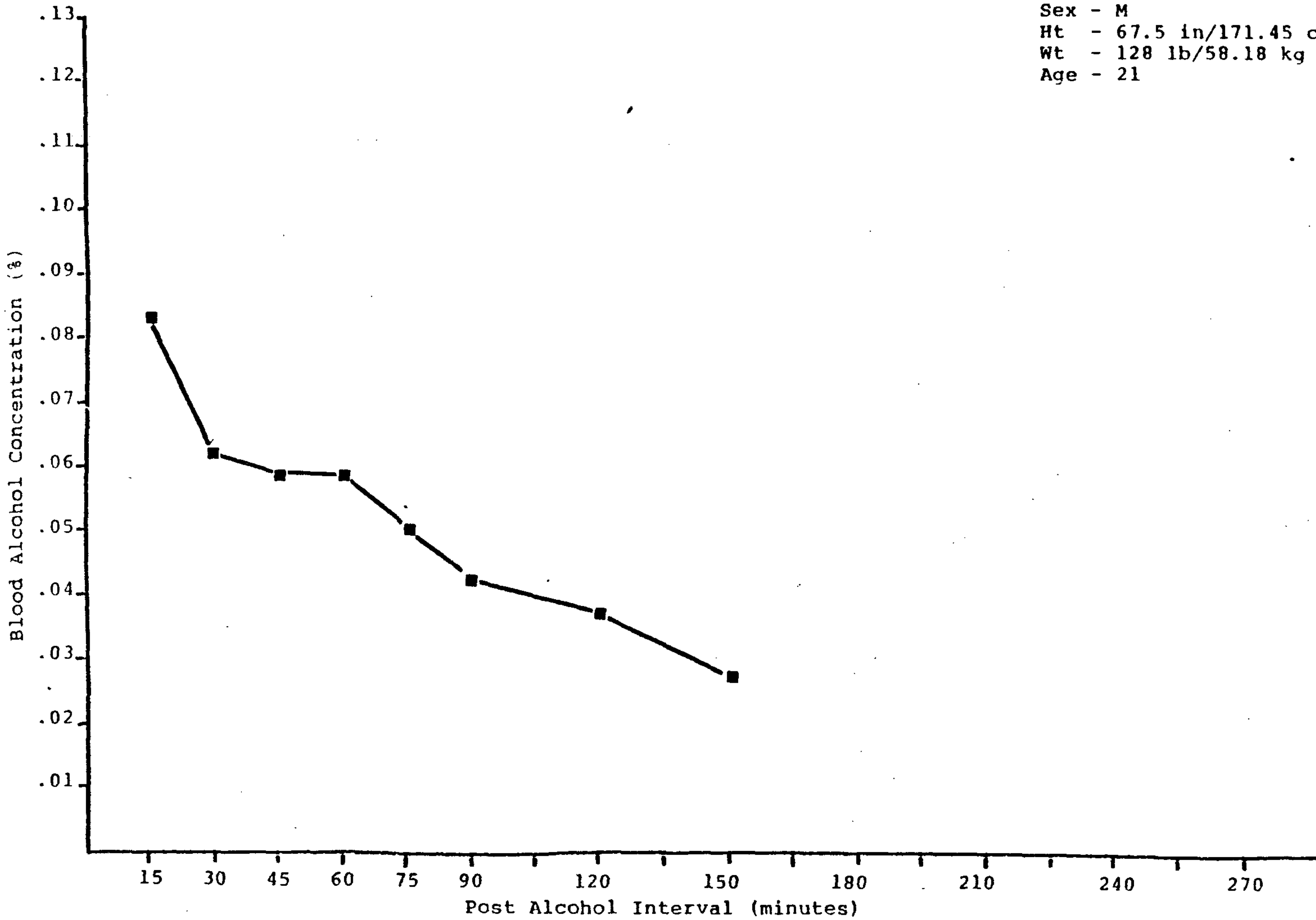
Sex - M
Ht - 74.25 in/188.60 cm
Wt - 186 lb/84.55 kg
Age - 28

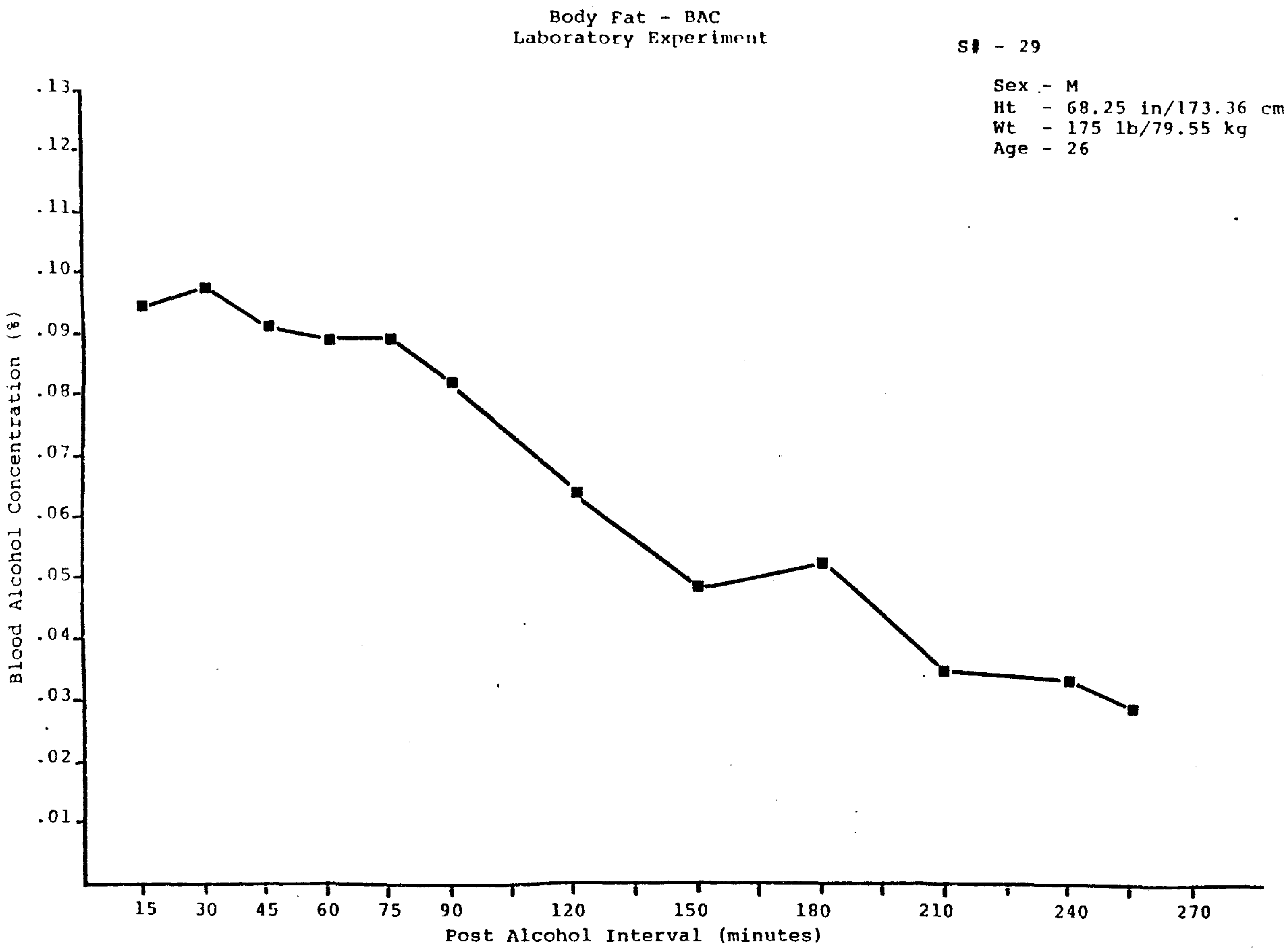


Body Fat - BAC
Laboratory Experiment

S# - 28

Sex - M
Ht - 67.5 in/171.45 cm
Wt - 128 lb/58.18 kg
Age - 21

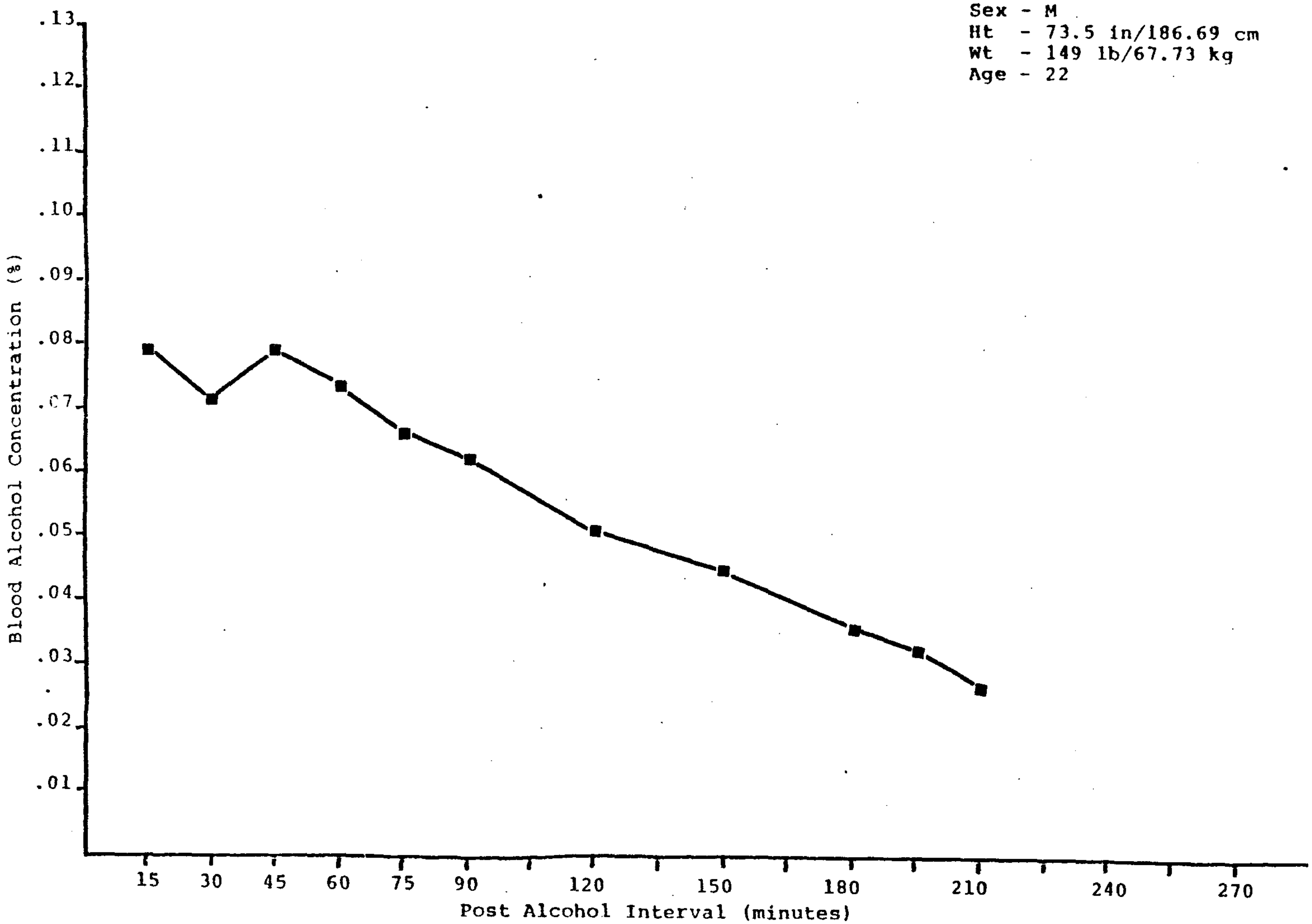



Body Fat - BAC
Laboratory Experiment
S# - 29
Sex - M
Ht - 68.25 in/173.36 cm
Wt - 175 lb/79.55 kg
Age - 26
Blood Alcohol Concentration (%)
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
15
30
45
60
75
90
120
150
180
210
240
270
Post Alcohol Interval (minutes)

Body Fat - BAC
Laboratory Experiment

S# - 30

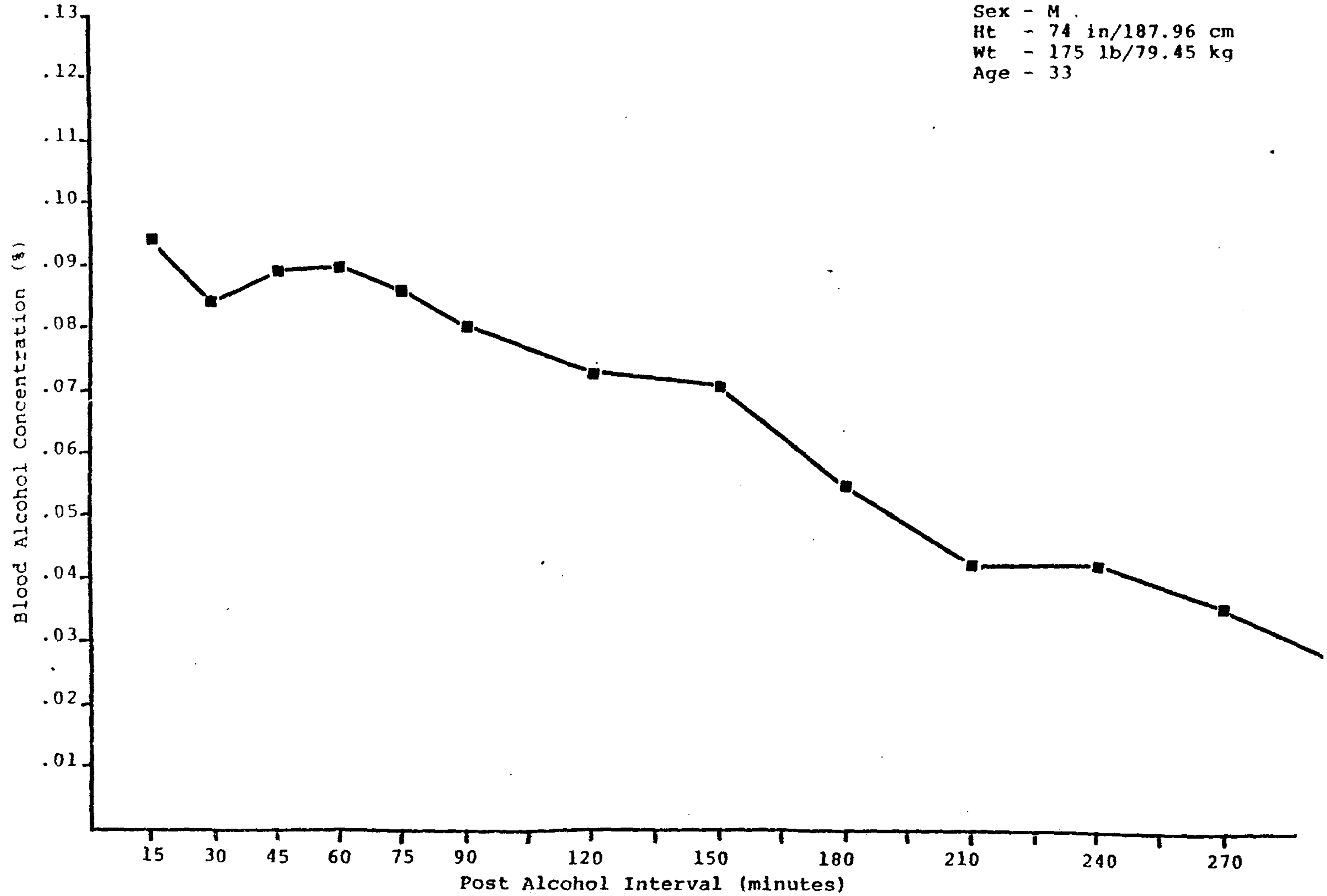
Sex - M
Ht - 73.5 in/186.69 cm
Wt - 149 lb/67.73 kg
Age - 22



Body Fat - BAC
Laboratory Experiment

S# - 31

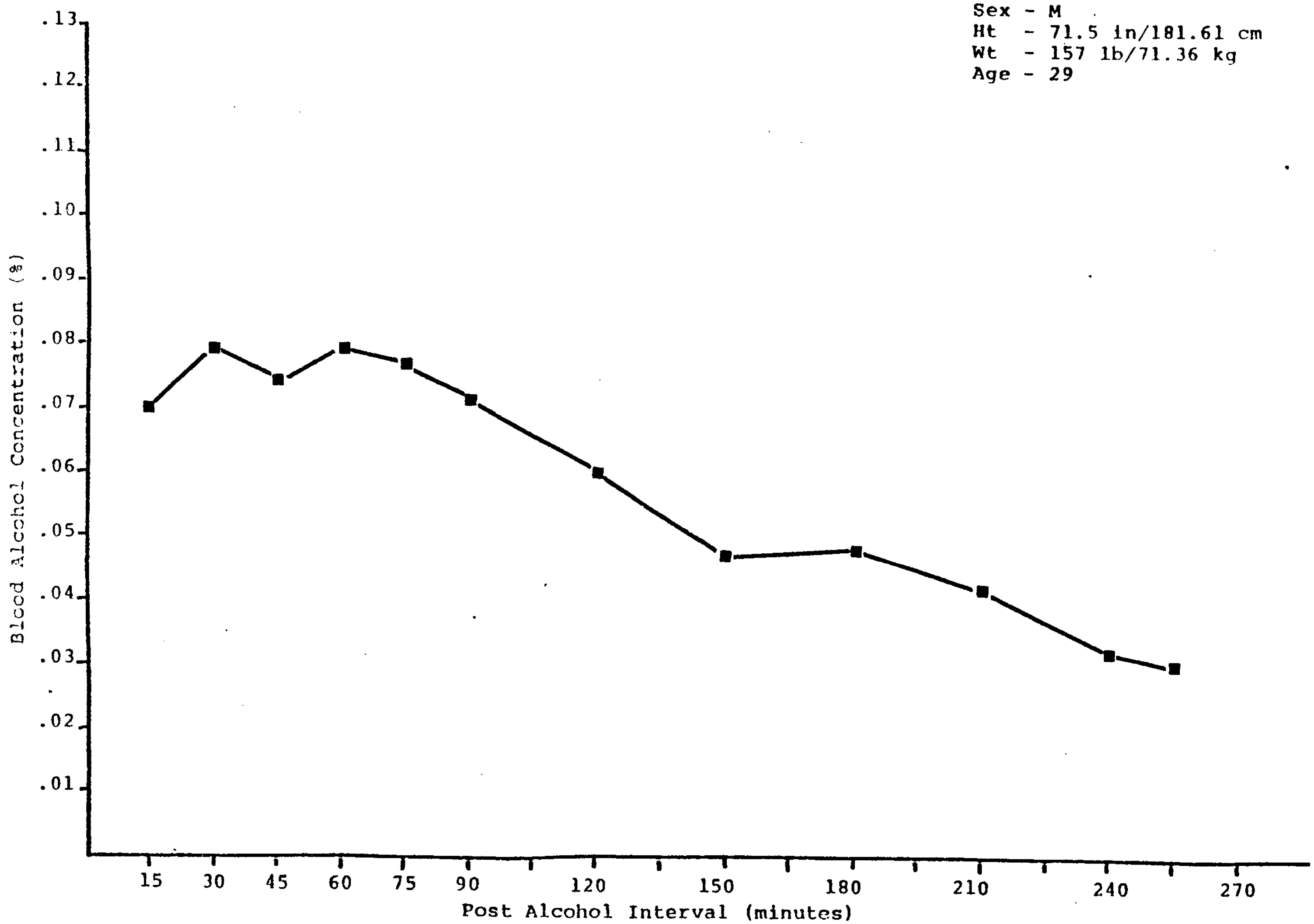
Sex - M
Ht - 74 in/187.96 cm
Wt - 175 lb/79.45 kg
Age - 33



Body Fat - BAC
Laboratory Experiment

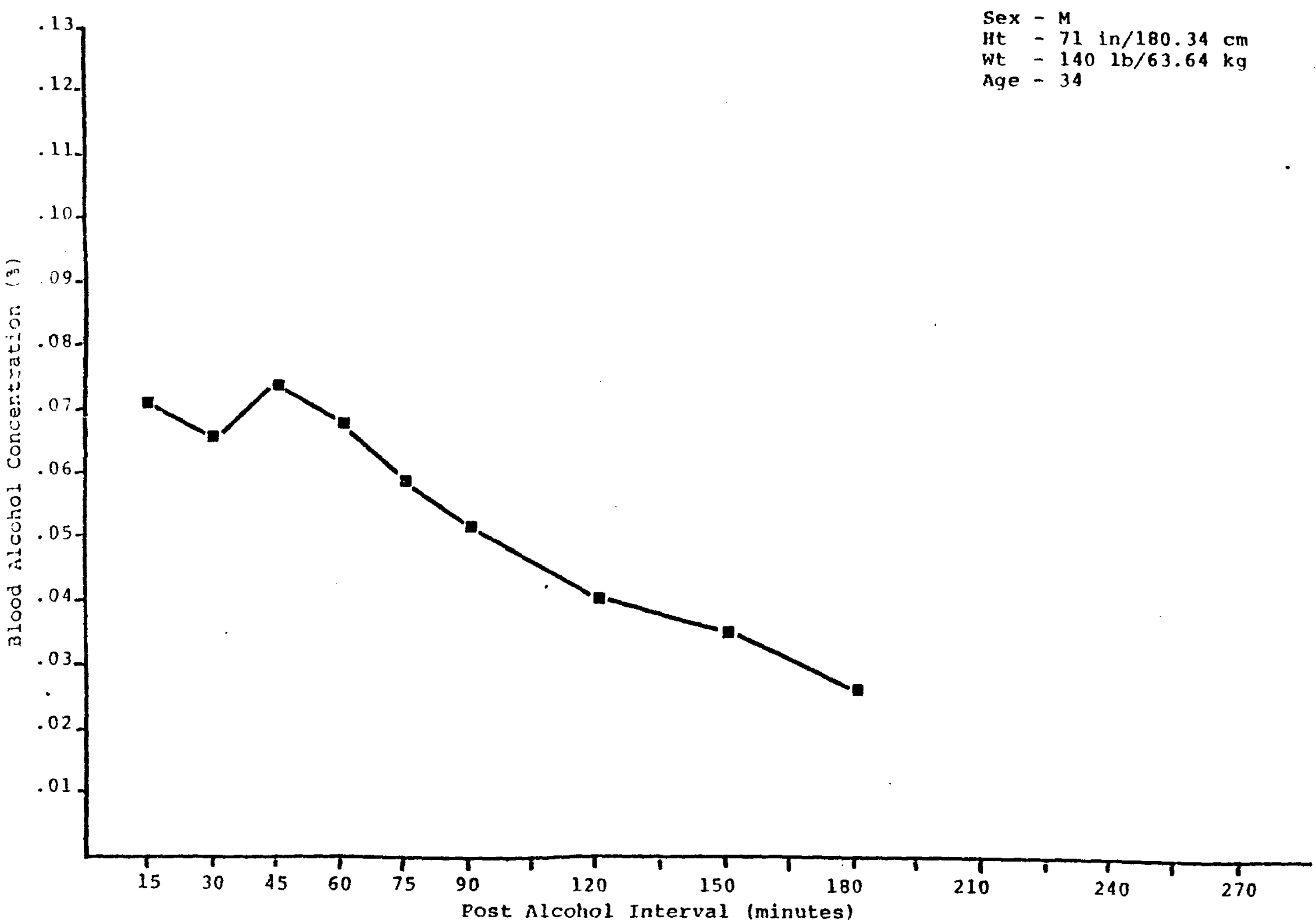
S# - 32

Sex - M
Ht - 71.5 in/181.61 cm
Wt - 157 lb/71.36 kg
Age - 29

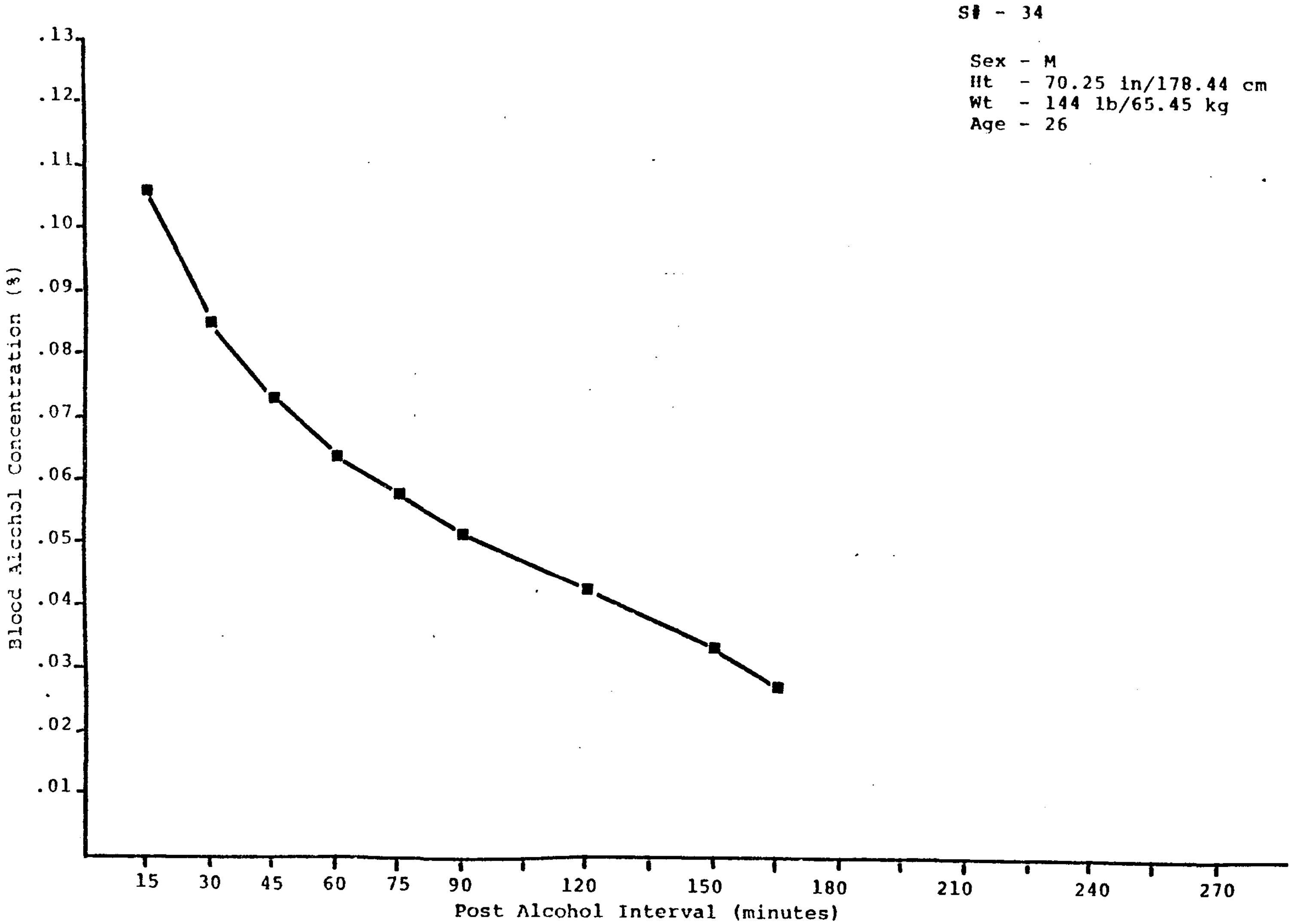


Body Fat - BAC
Laboratory Experiment

S# - 33

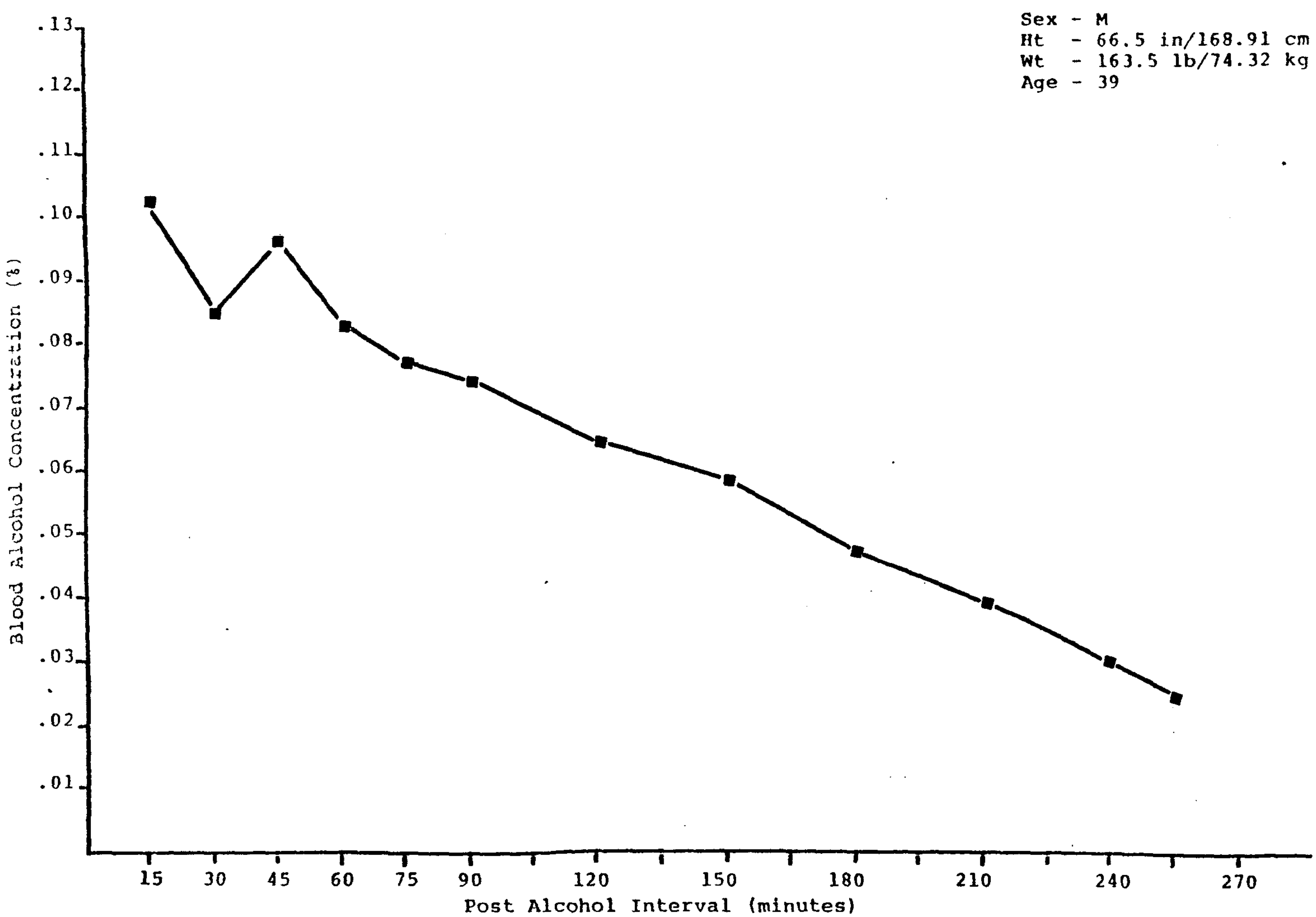


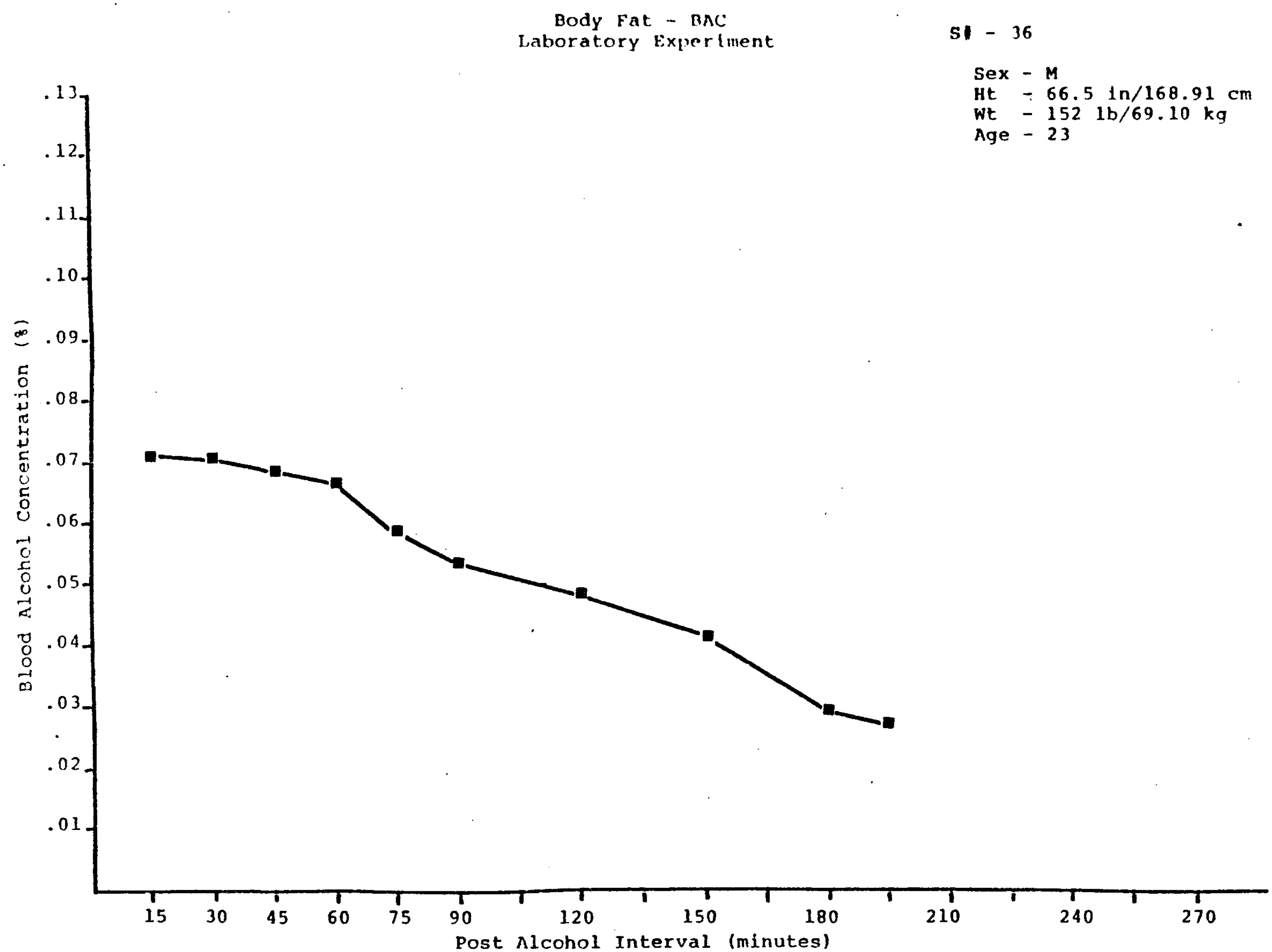
Body Fat - BAC
Laboratory Experiment



Body Fat - BAC
Laboratory Experiment

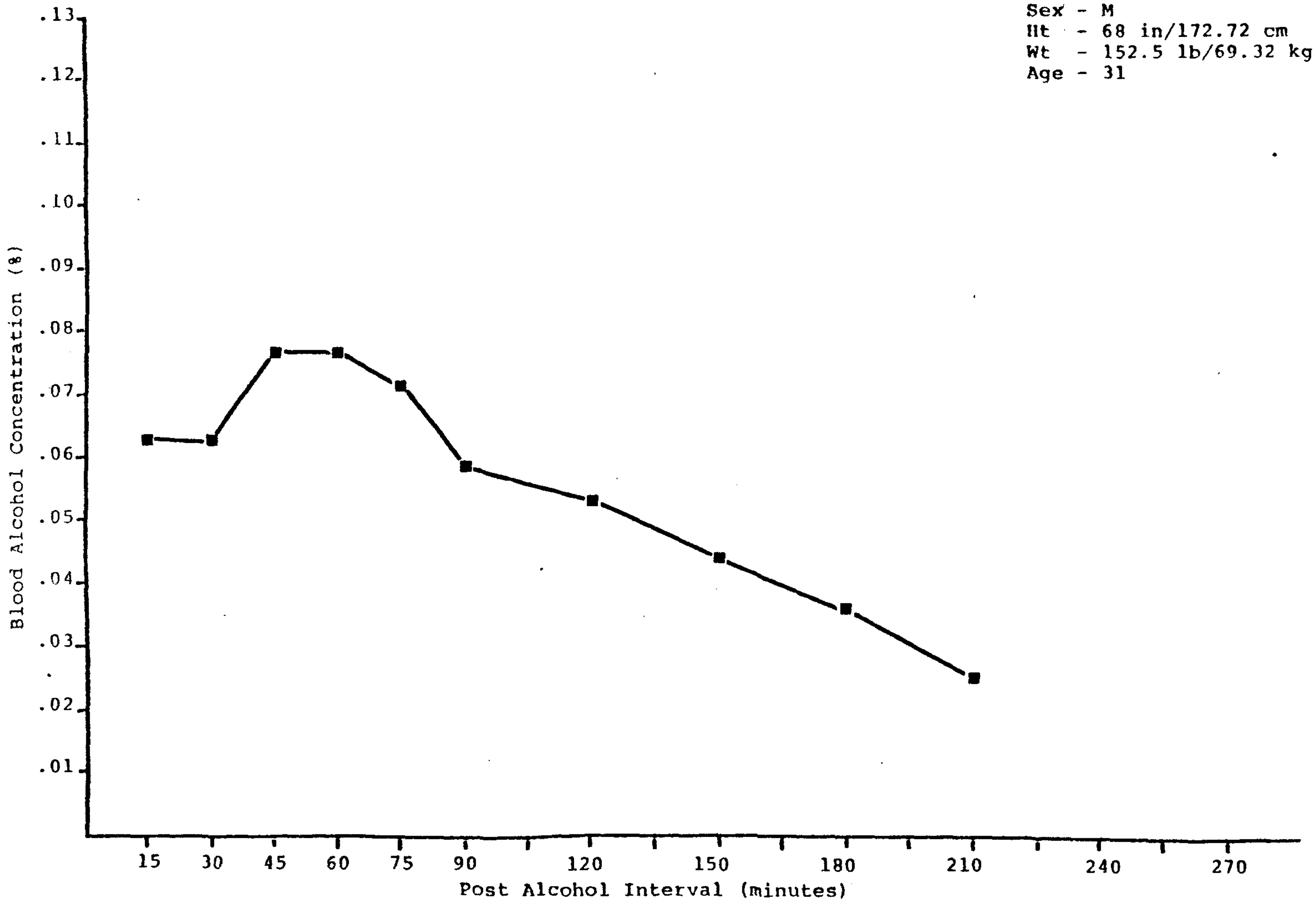
S# - 35




Body Fat - BAC
Laboratory Experiment
S# - 36
Sex - M
Ht - 66.5 in/168.91 cm
Wt - 152 lb/69.10 kg
Age - 23
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
Blood Alcohol Concentration (%)
15
30
45
60
75
90
120
150
180
210
240
270
Post Alcohol Interval (minutes)

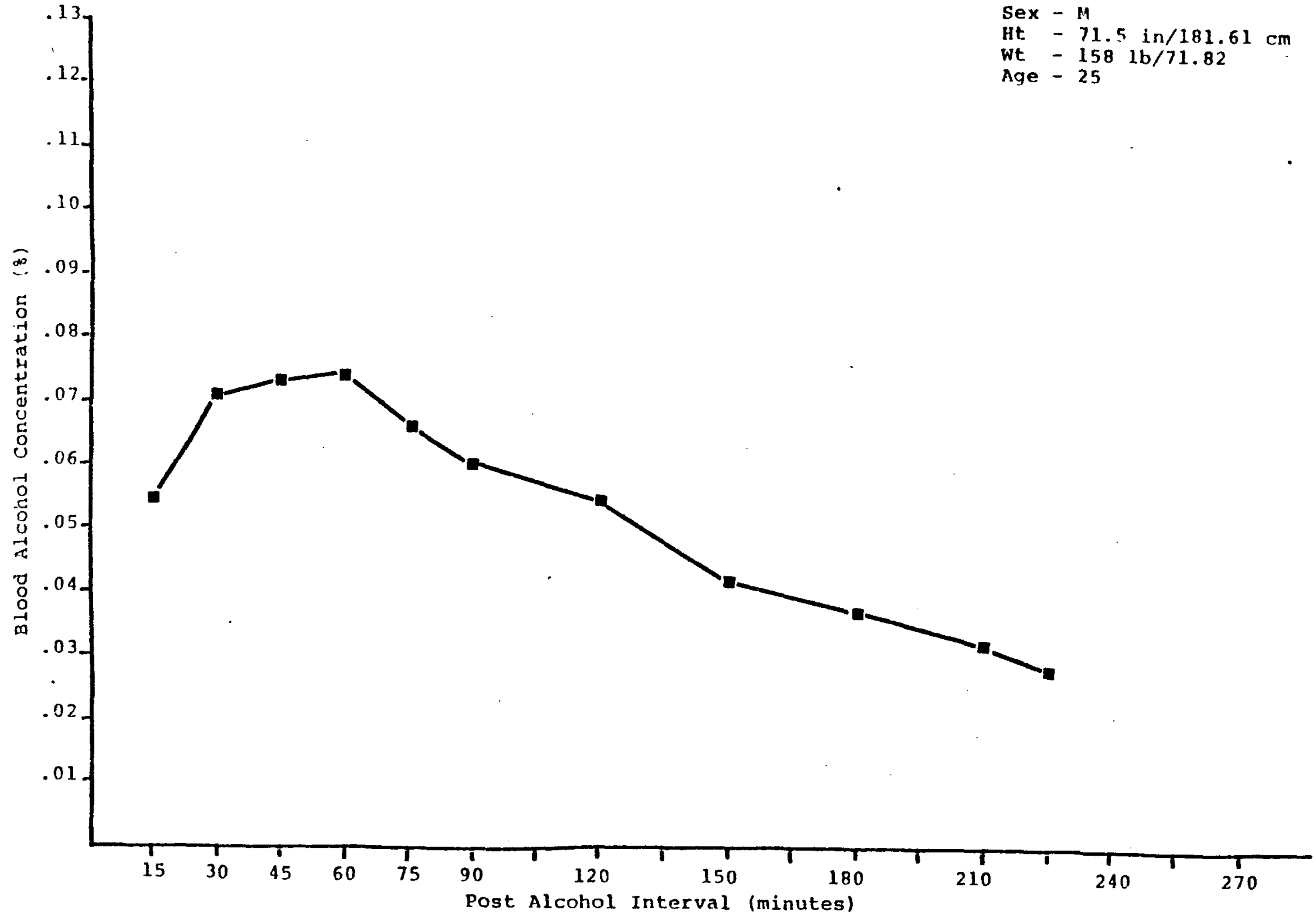
Body Fat - BAC
Laboratory Experiment

S# - 37



Body Fat - BAC
Laboratory Experiment

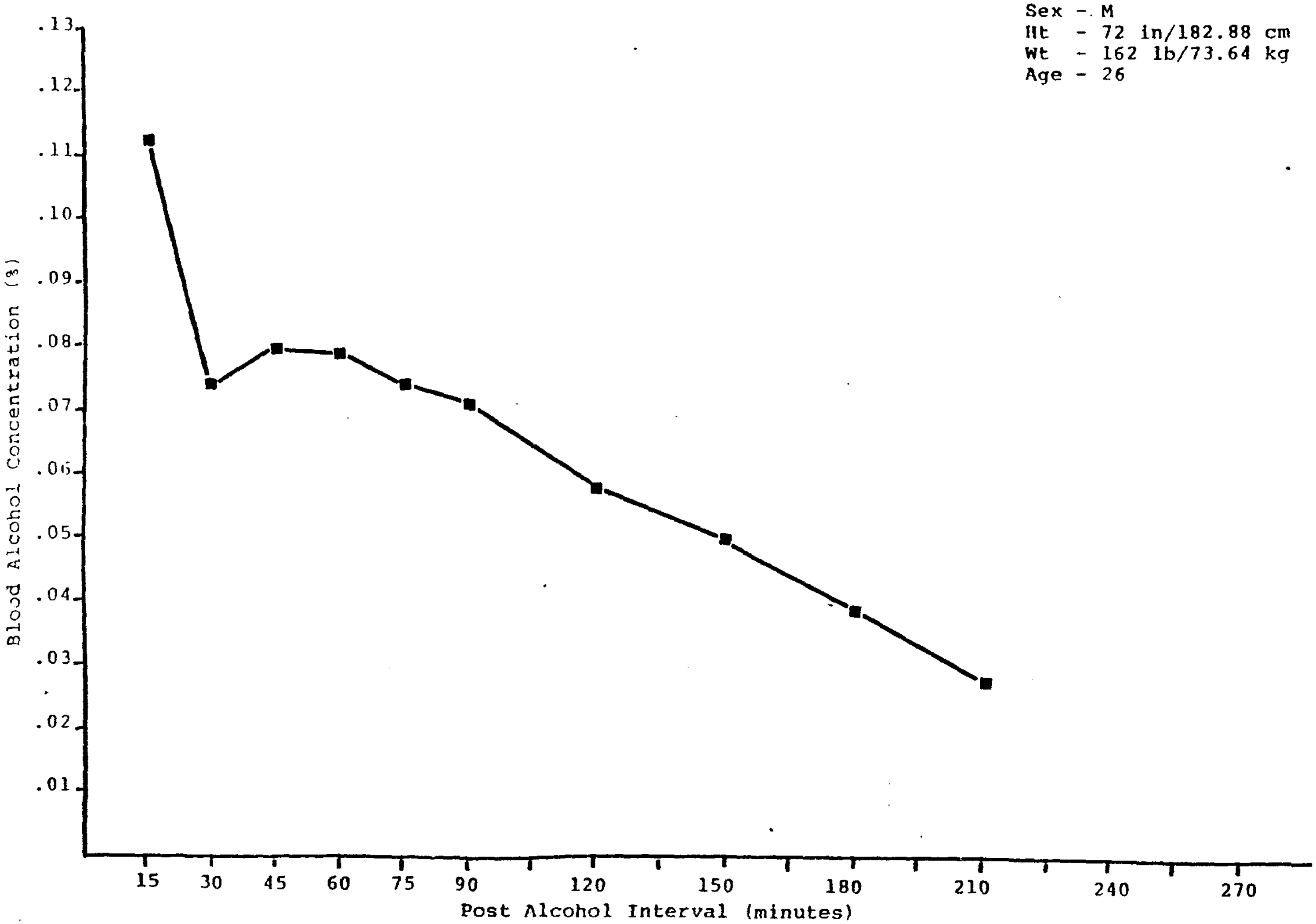
S# - 38



Body Fat - BAC
Laboratory Experiment

S# - 39

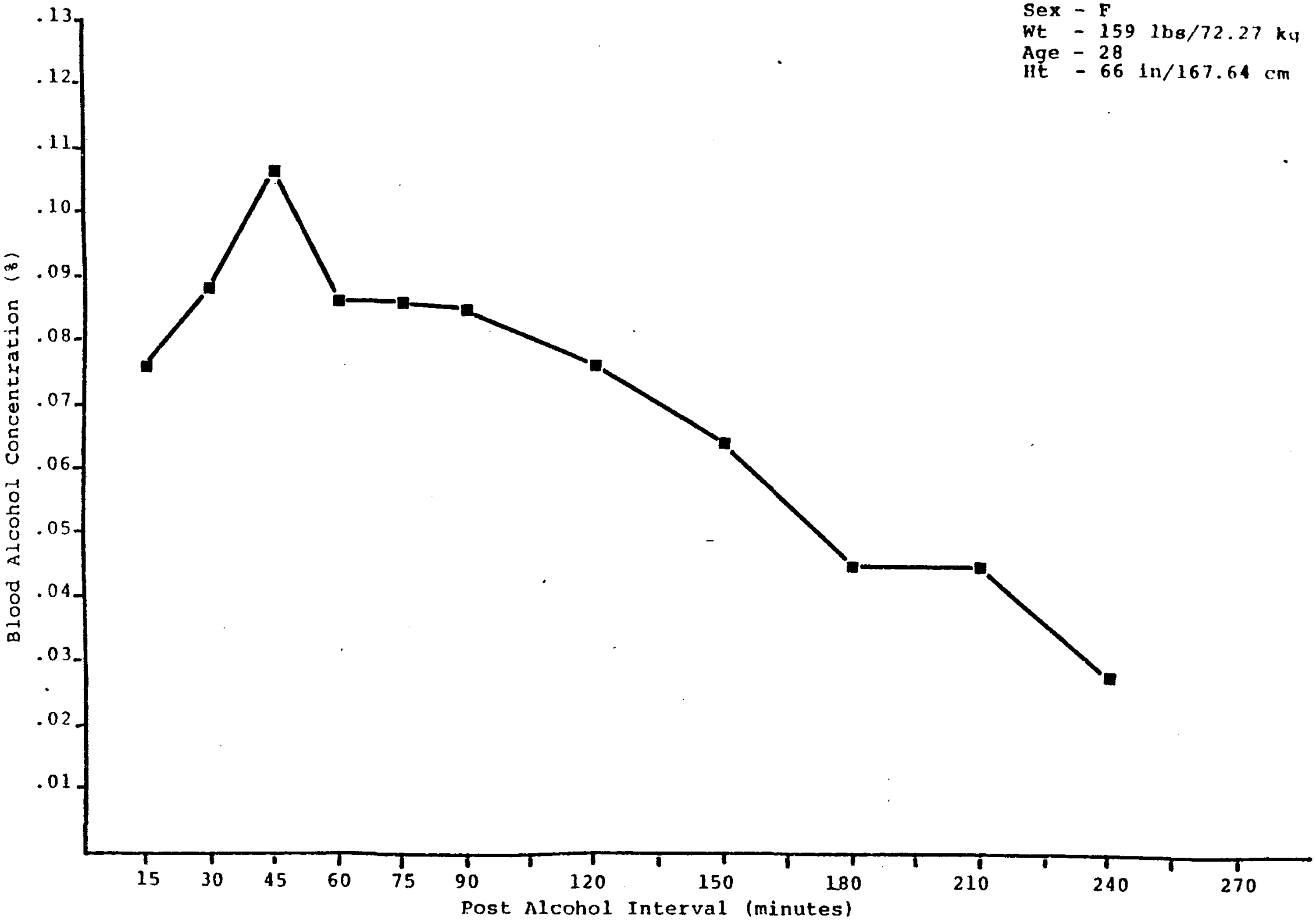
Sex - M
Ht - 72 in/182.88 cm
Wt - 162 lb/73.64 kg
Age - 26



Body Fat - BAC
Laboratory Experiment

S# - 40

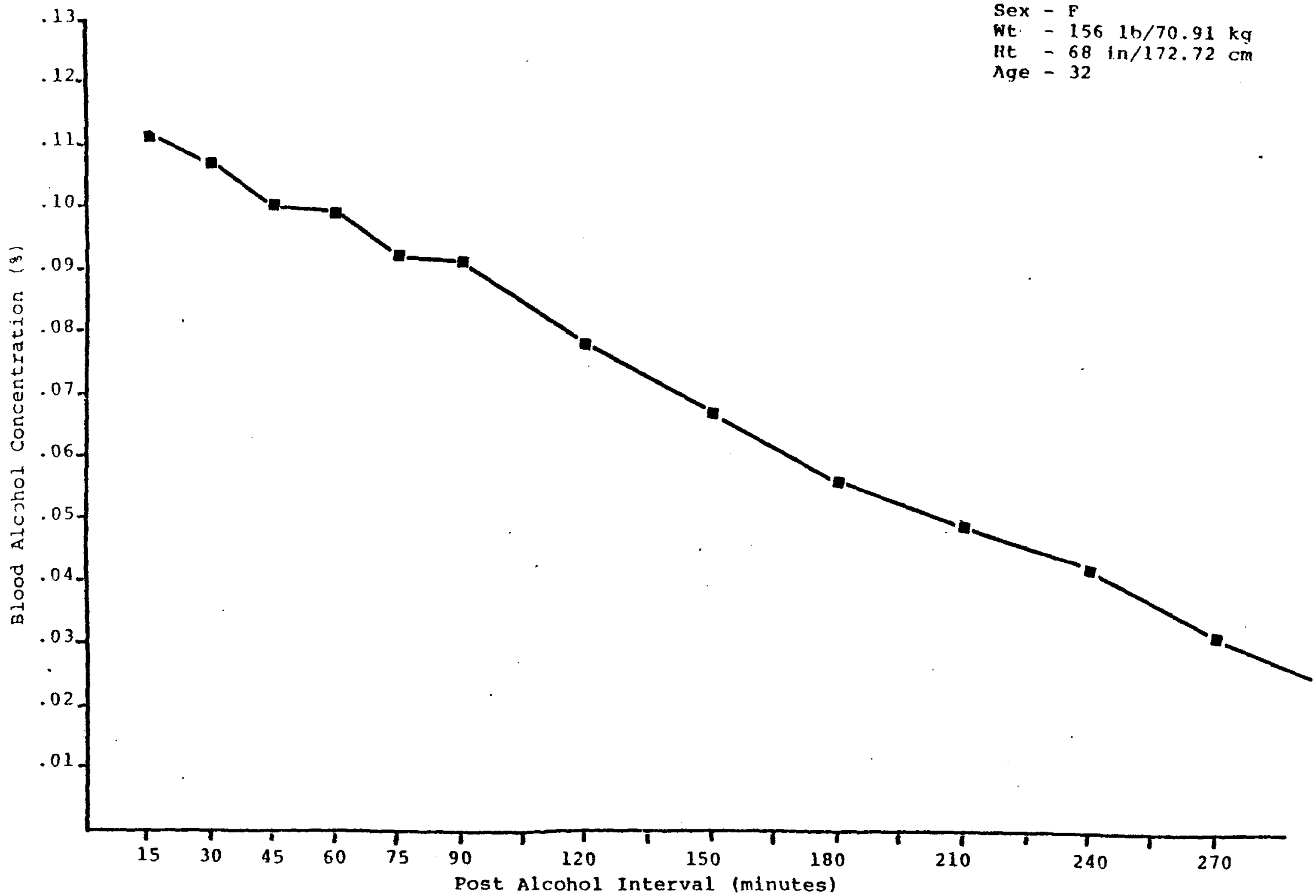
Sex - F
Wt - 159 lbs/72.27 kg
Age - 28
Ht - 66 in/167.64 cm



Body Fat - BAC
Laboratory Experiment

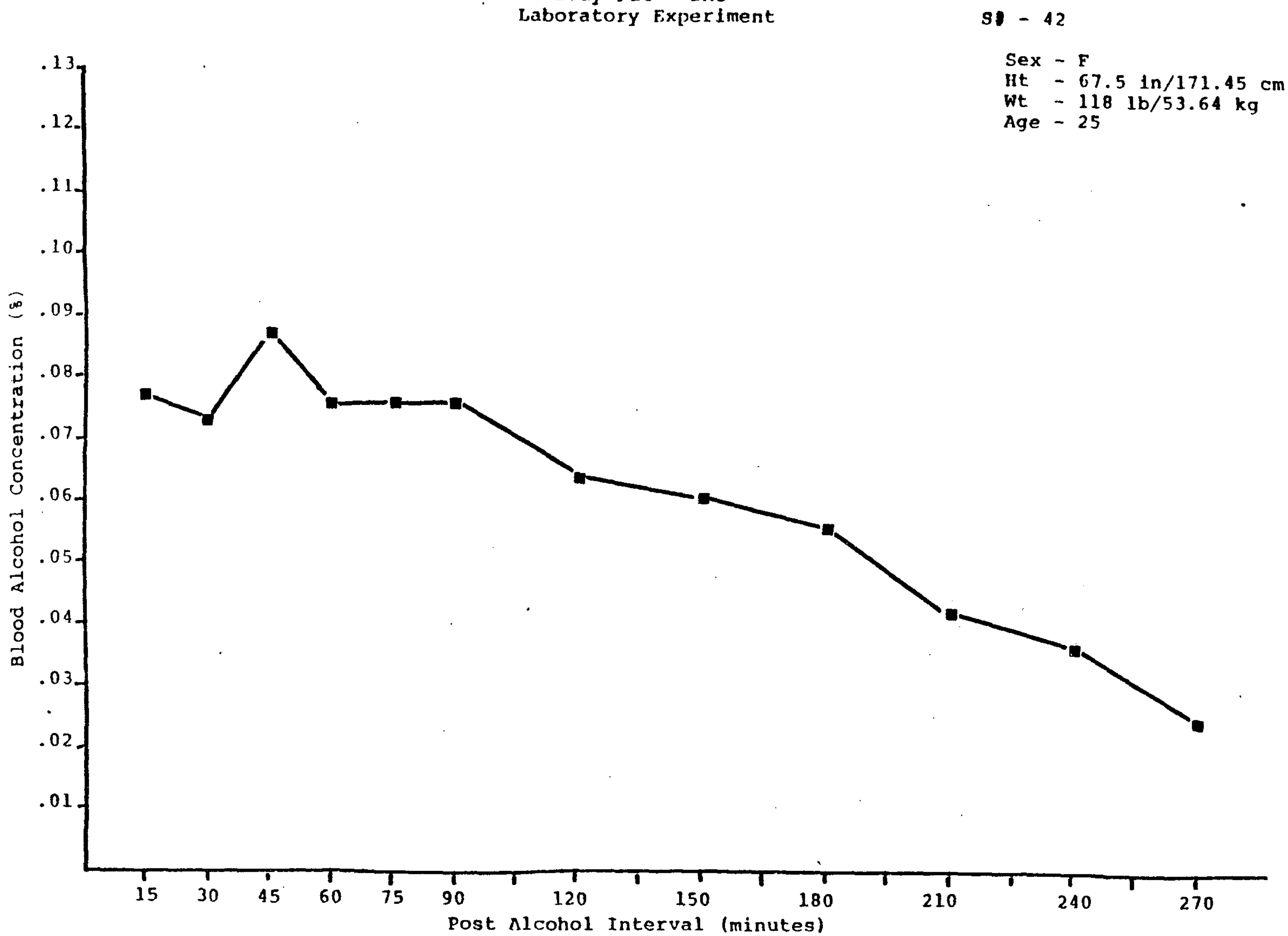
S# - 41

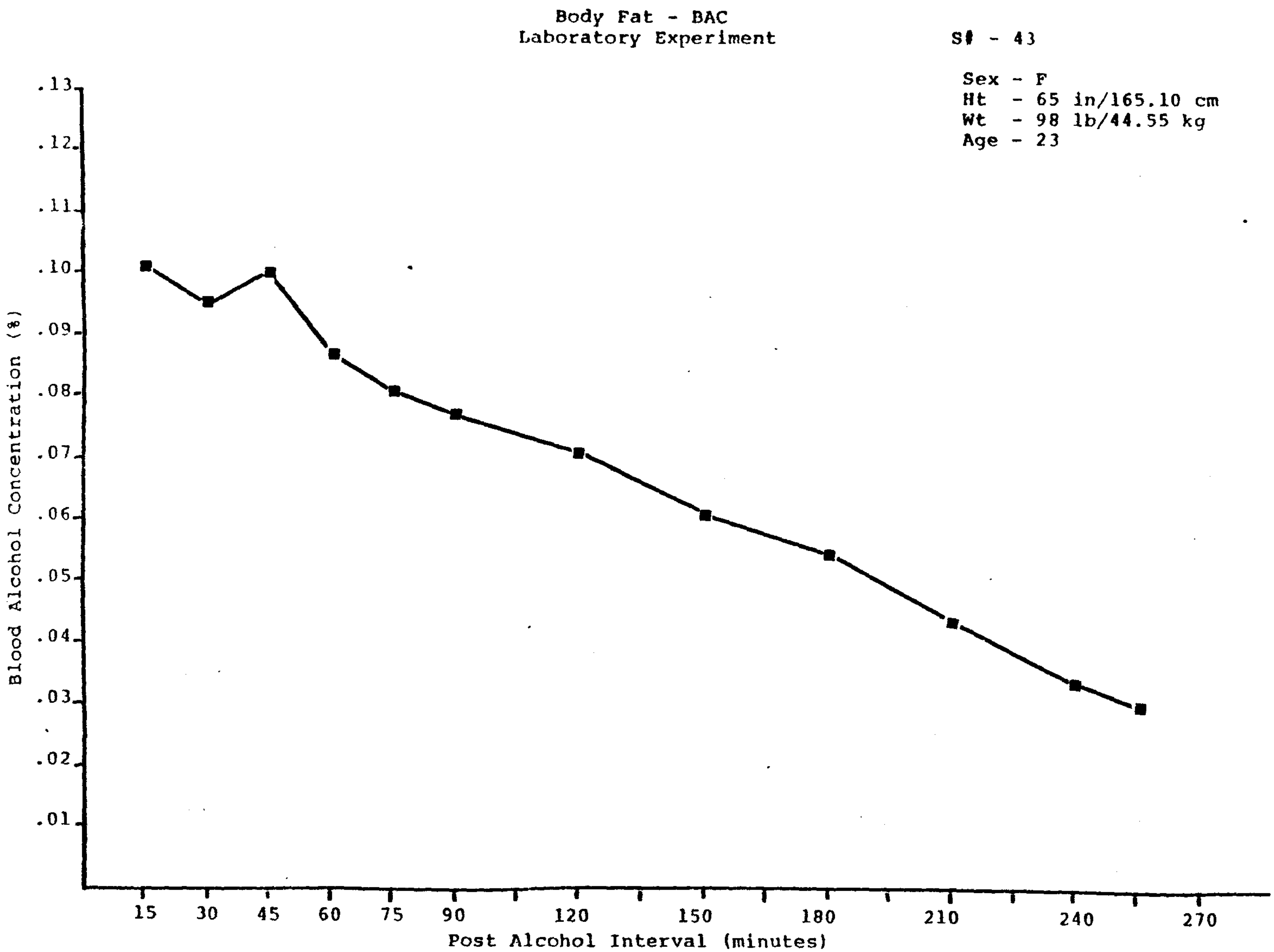
Sex - F
Wt - 156 lb/70.91 kg
Ht - 68 in/172.72 cm
Age - 32



81.

Body Fat - BAC
Laboratory Experiment

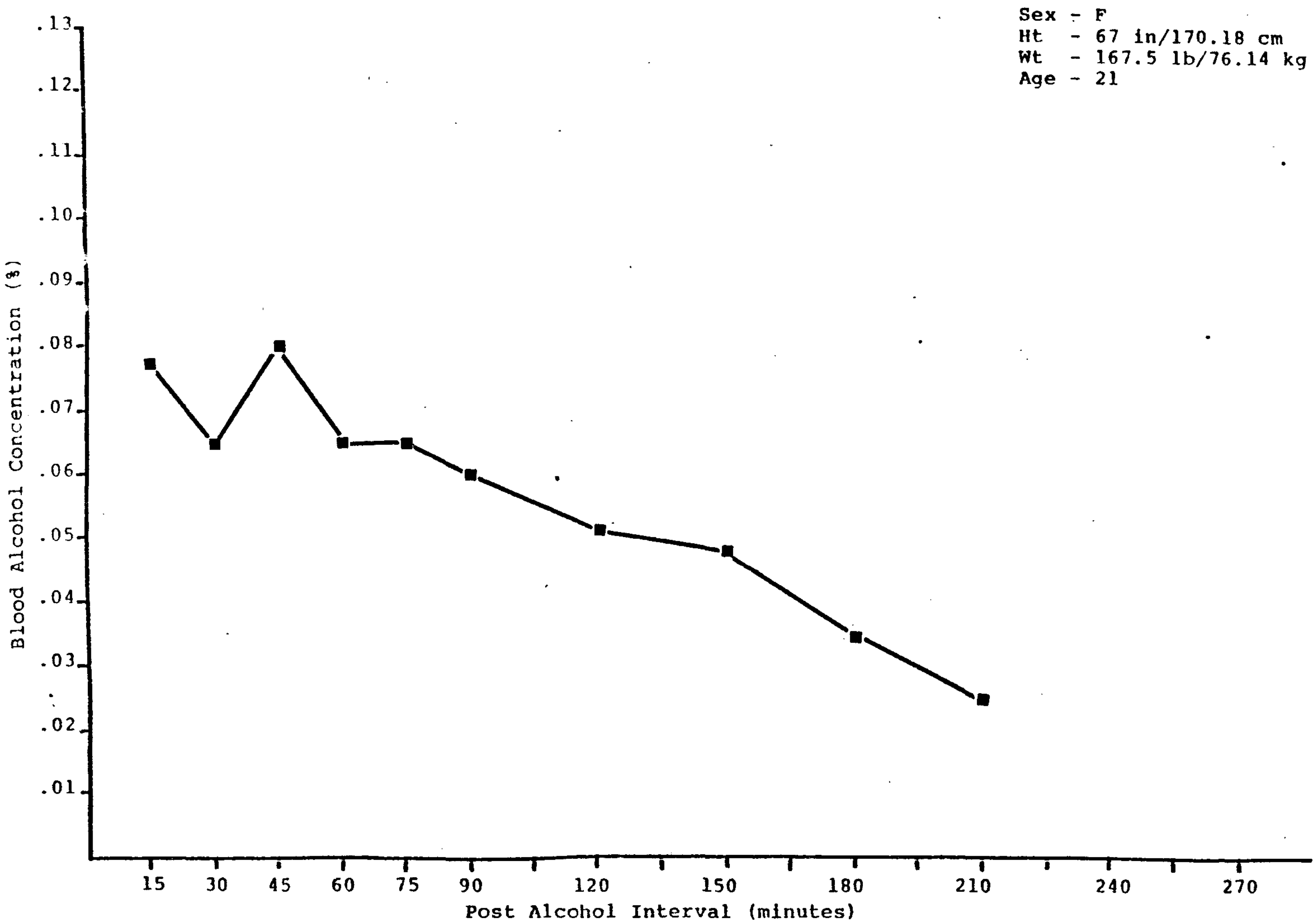



Body Fat - BAC
Laboratory Experiment
S# - 43
Sex - F
Ht - 65 in/165.10 cm
Wt - 98 lb/44.55 kg
Age - 23
Blood Alcohol Concentration (%)
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
15
30
45
60
75
90
120
150
180
210
240
270
Post Alcohol Interval (minutes)

83.

Body Fat - BAC
Laboratory Experiment

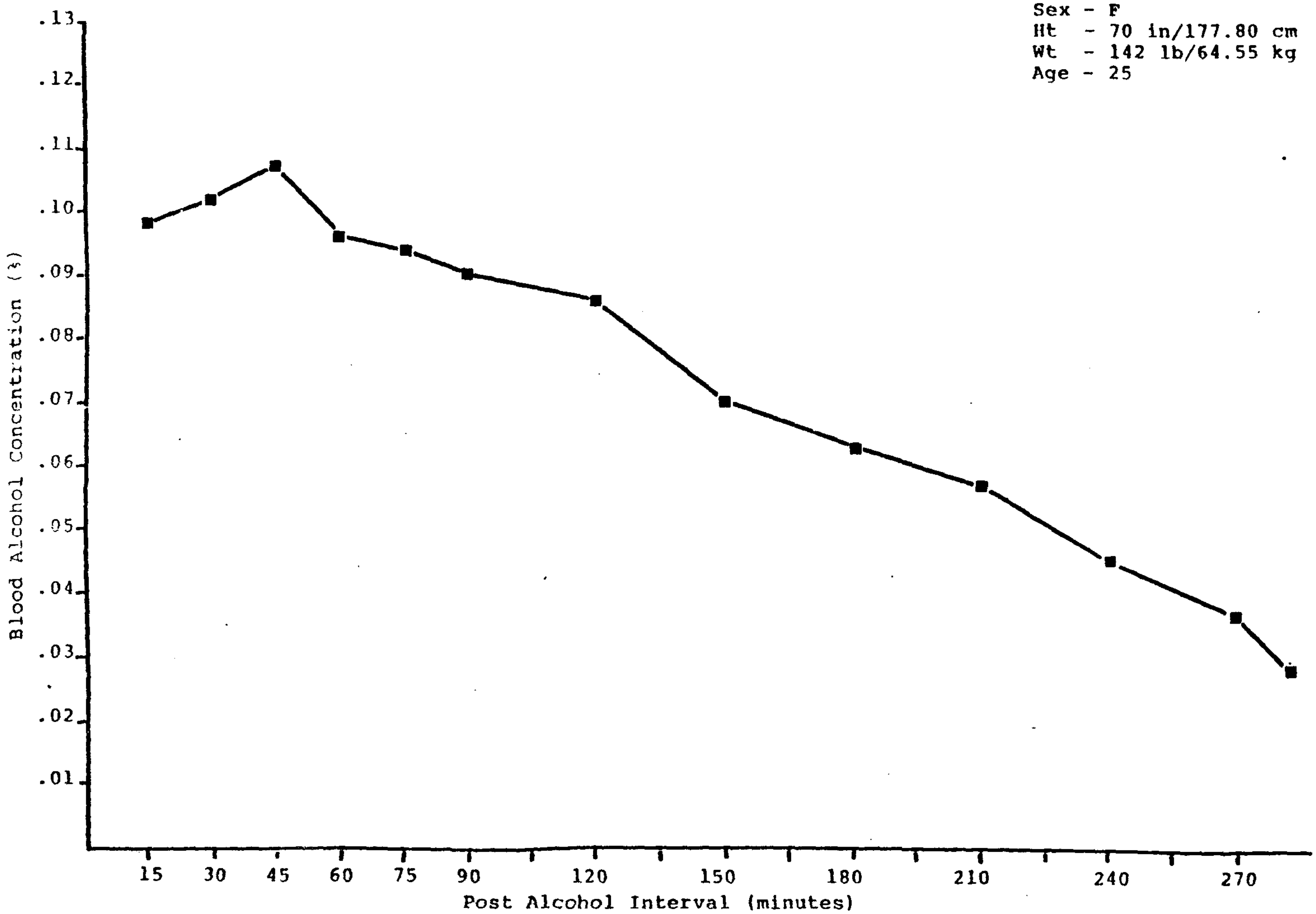
S# - 44



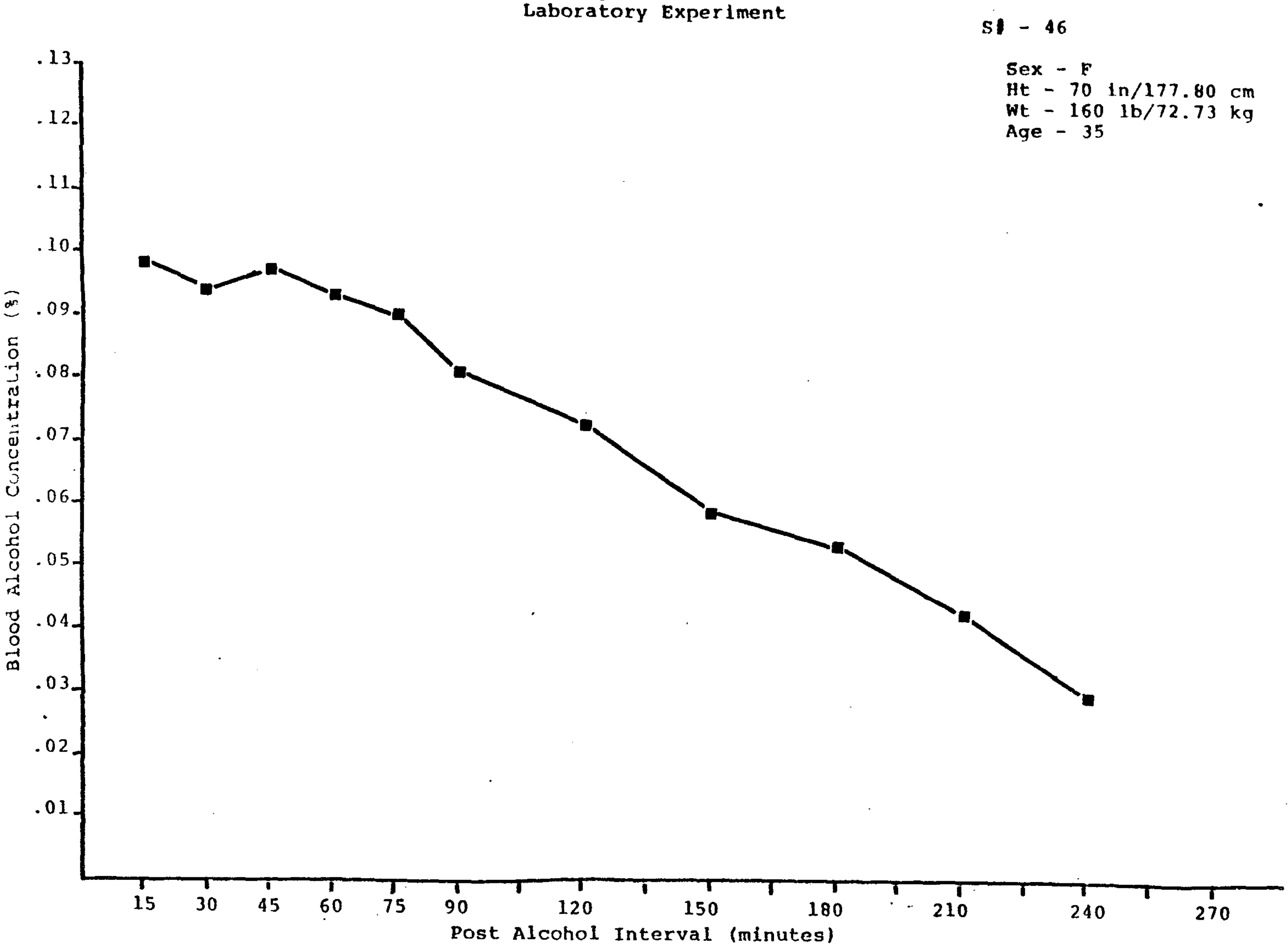
Body Fat - BAC
Laboratory Experiment

S# - 45

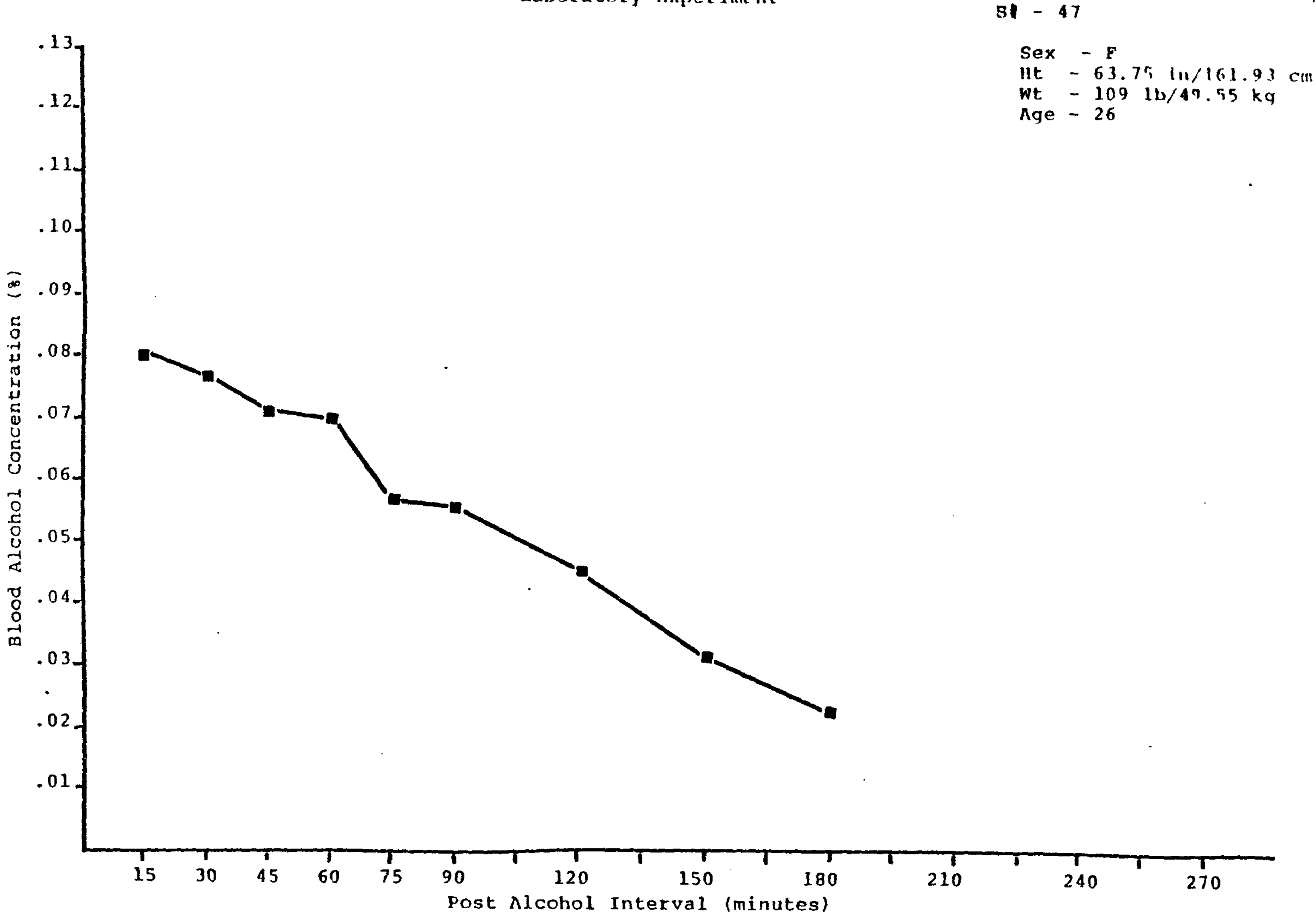
Sex - F
Ht - 70 in/177.80 cm
Wt - 142 lb/64.55 kg
Age - 25



Body Fat - BAC
Laboratory Experiment



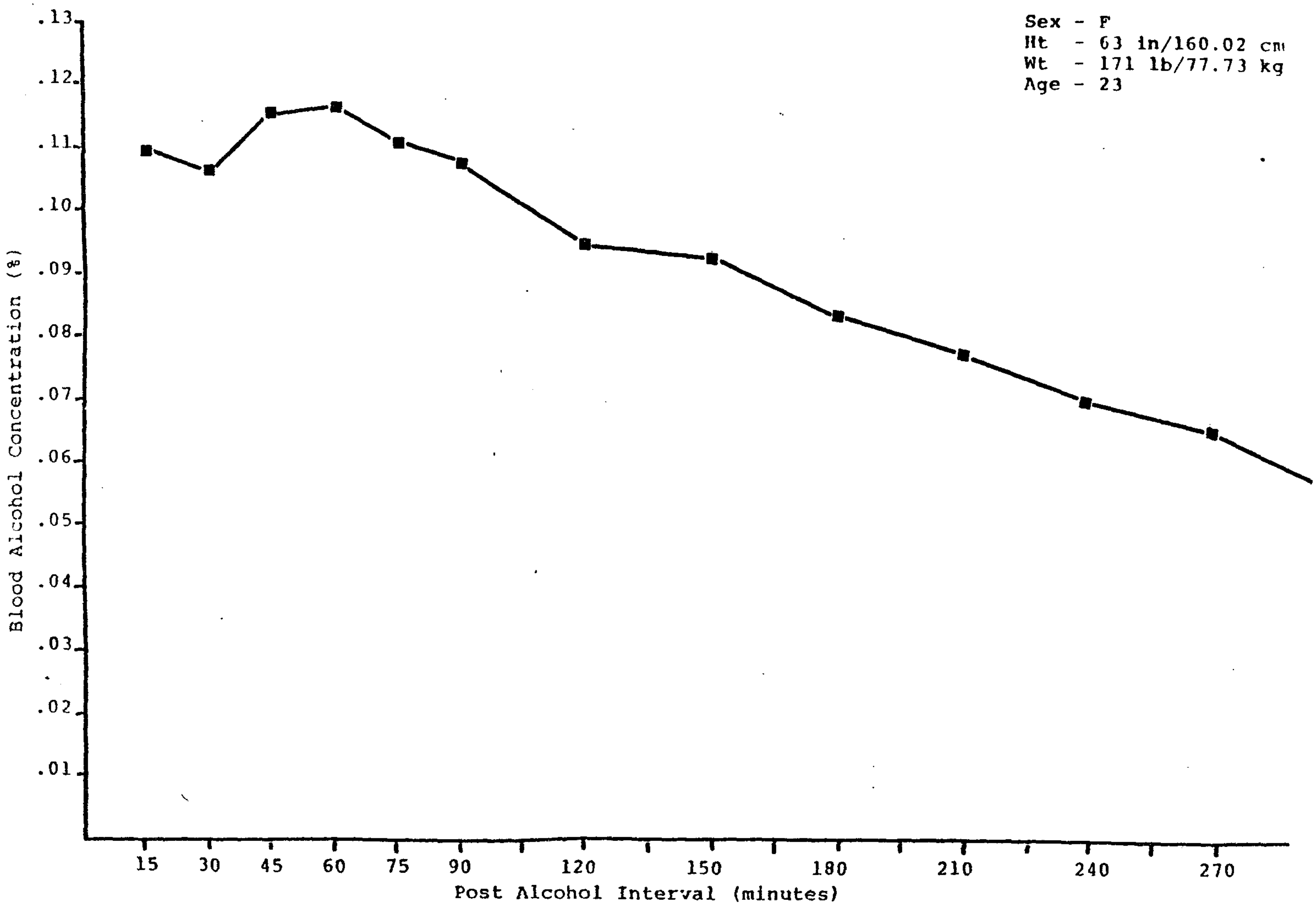
Body Fat - BAC
Laboratory Experiment



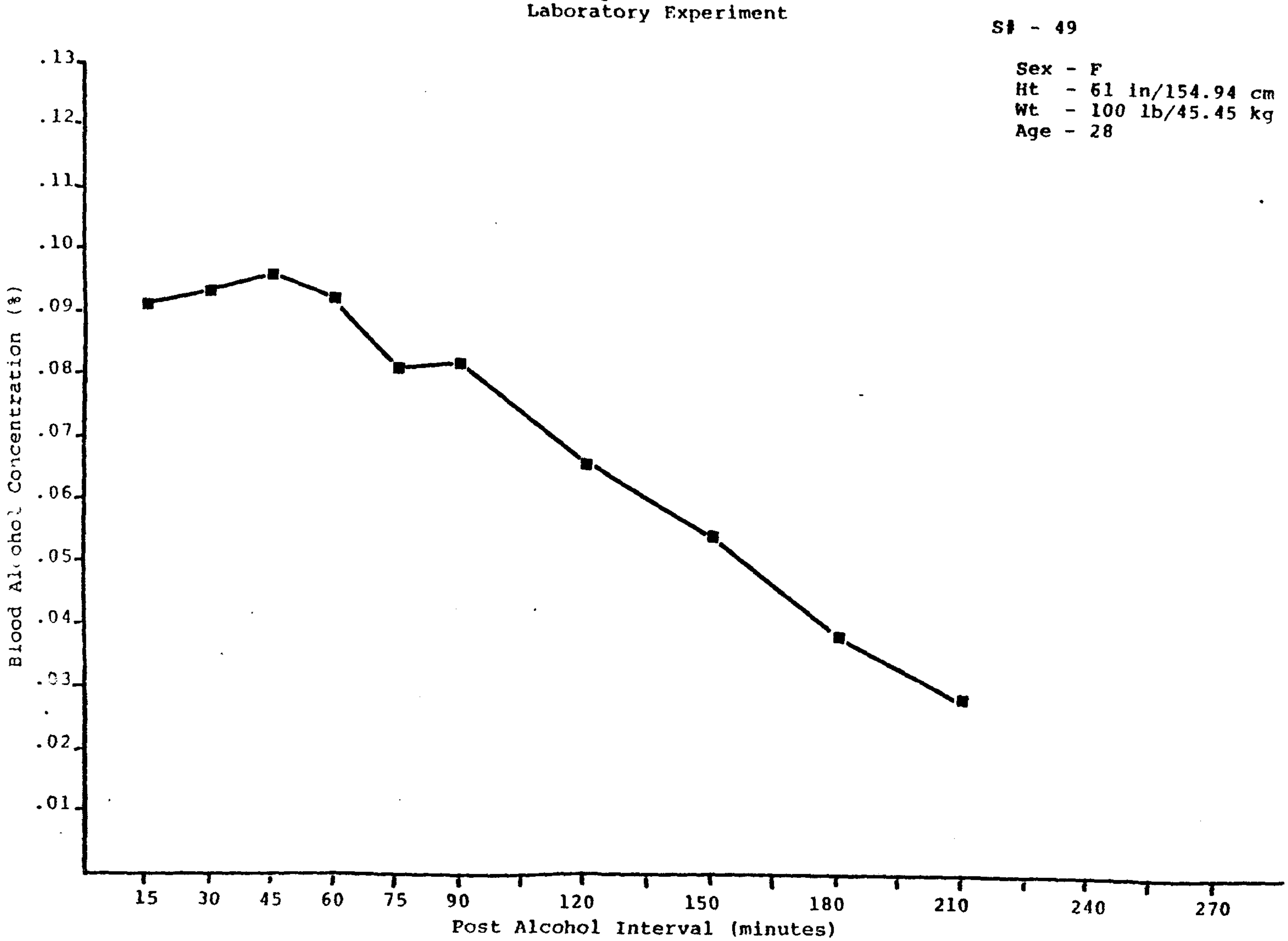
Body Fat - BAC
Laboratory Experiment

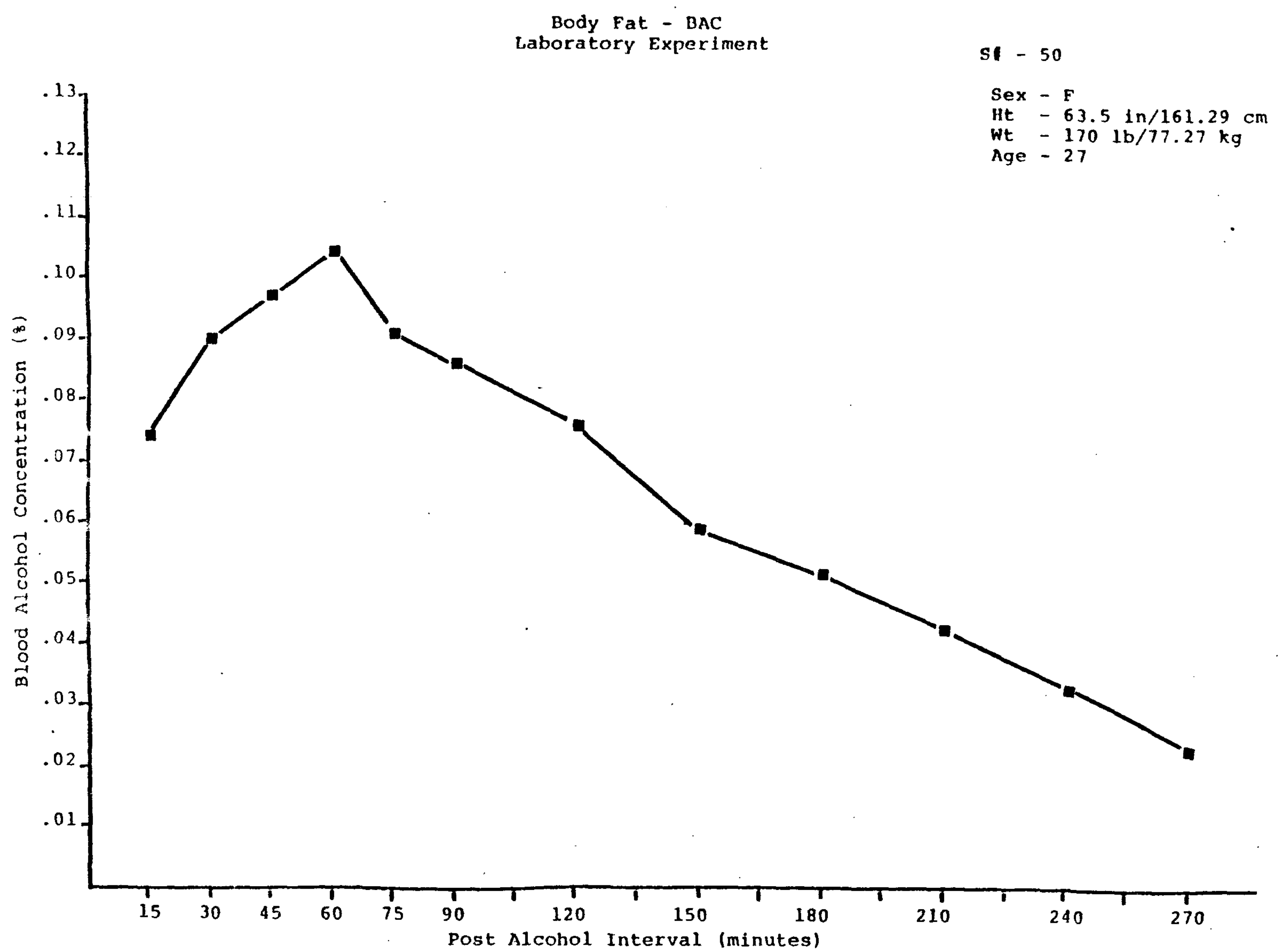
S# - 48

Sex - F
Ht - 63 in/160.02 cm
Wt - 171 lb/77.73 kg
Age - 23



Body Fat - BAC
Laboratory Experiment

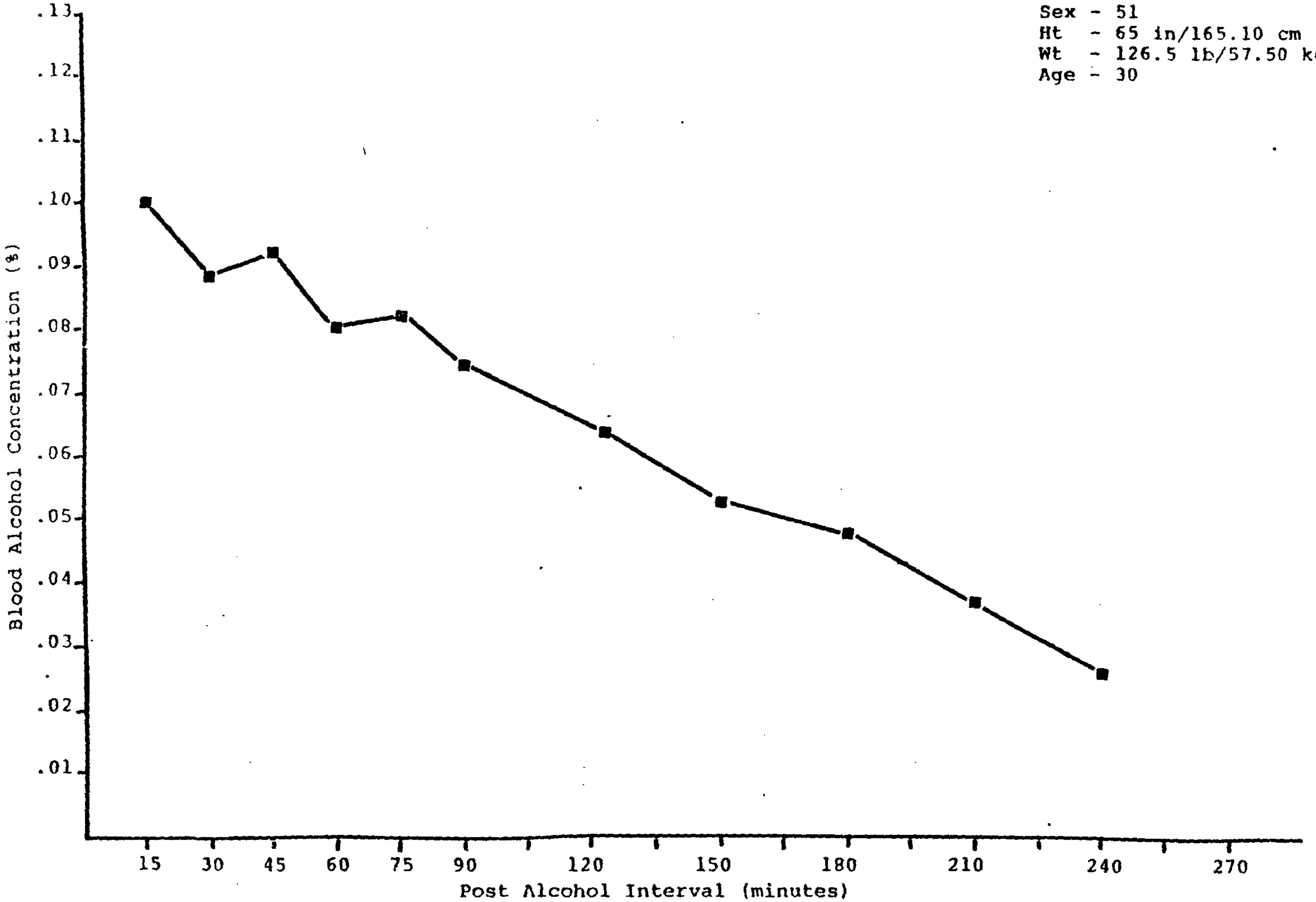


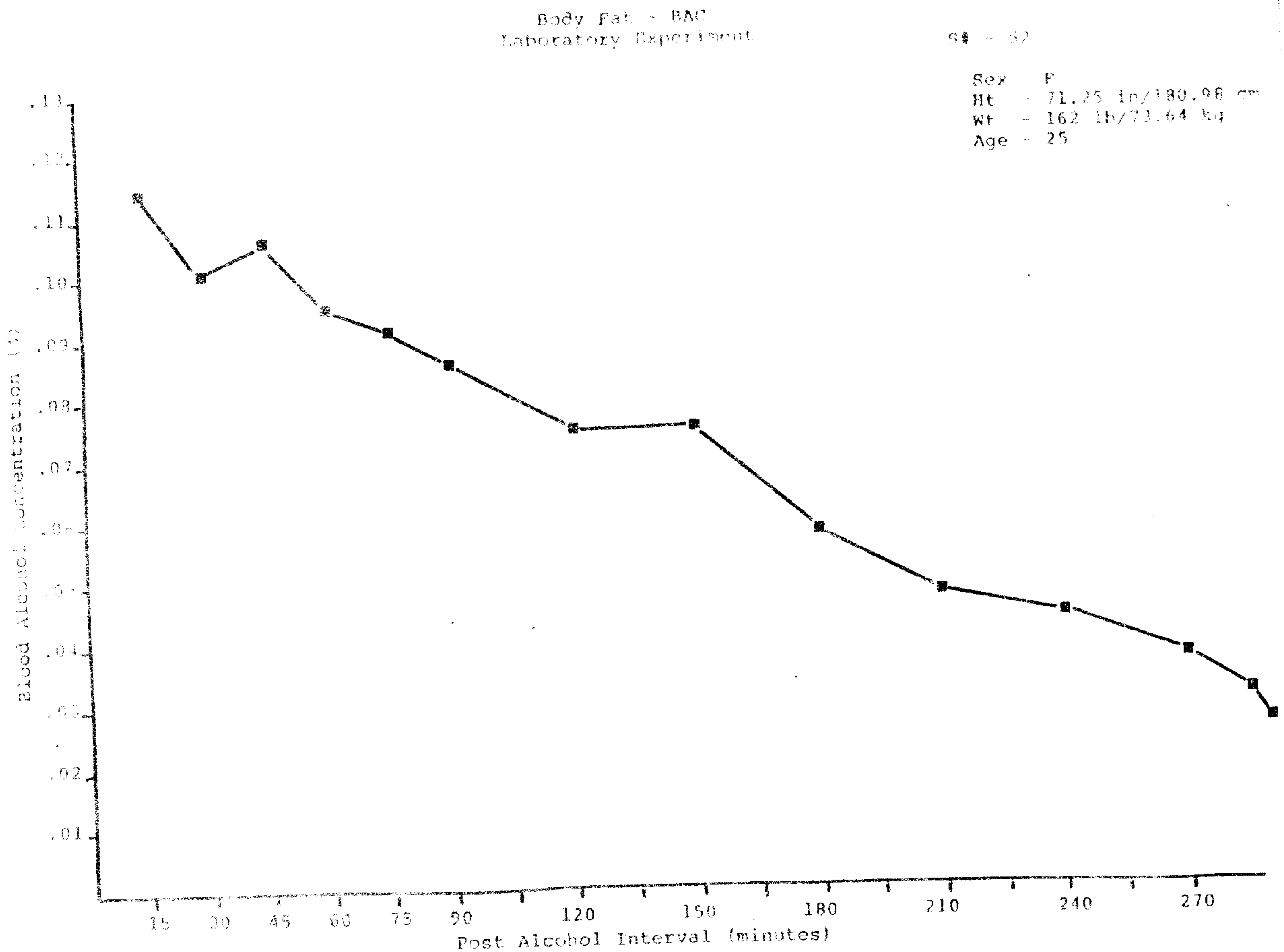

Body Fat - BAC
Laboratory Experiment
S# - 50
Sex - F
Ht - 63.5 in/161.29 cm
Wt - 170 lb/77.27 kg
Age - 27
Blood Alcohol Concentration (%)
.13
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
15
30
45
60
75
90
120
150
180
210
240
270
Post Alcohol Interval (minutes)

Body Fat - BAC
Laboratory Experiment

S# - 51

Sex - 51
Ht - 65 in/165.10 cm
Wt - 126.5 lb/57.50 kg
Age - 30



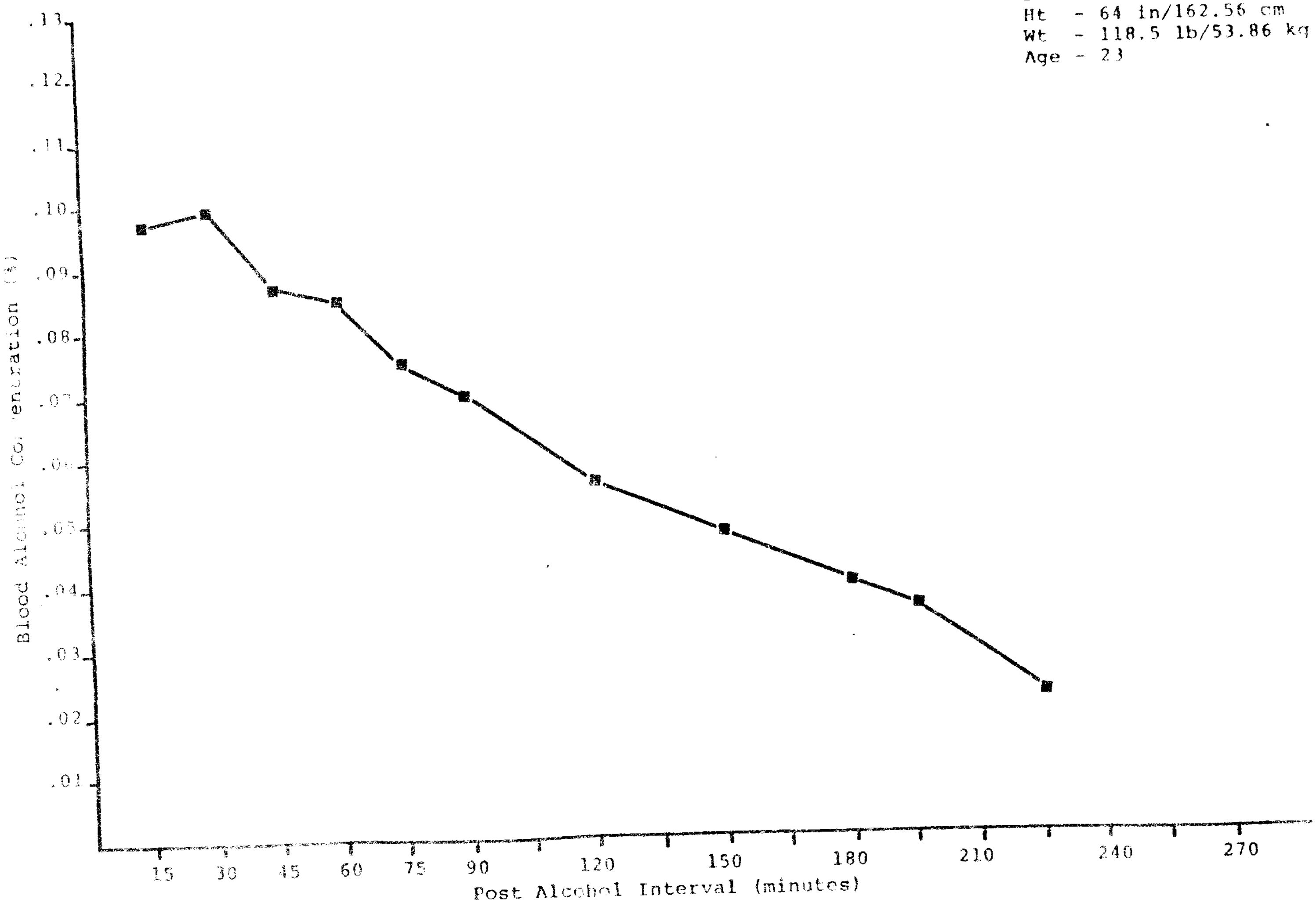

Body Fat - BAC
Laboratory Experiment
S# - 52
Sex - F
Ht - 71.25 in/180.98 cm
Wt - 162 lb/73.64 kg
Age - 25
Blood Alcohol Concentration (%)
Post Alcohol Interval (minutes)

-12-

Body Fat - BAC
Laboratory Experiment

S# - 53

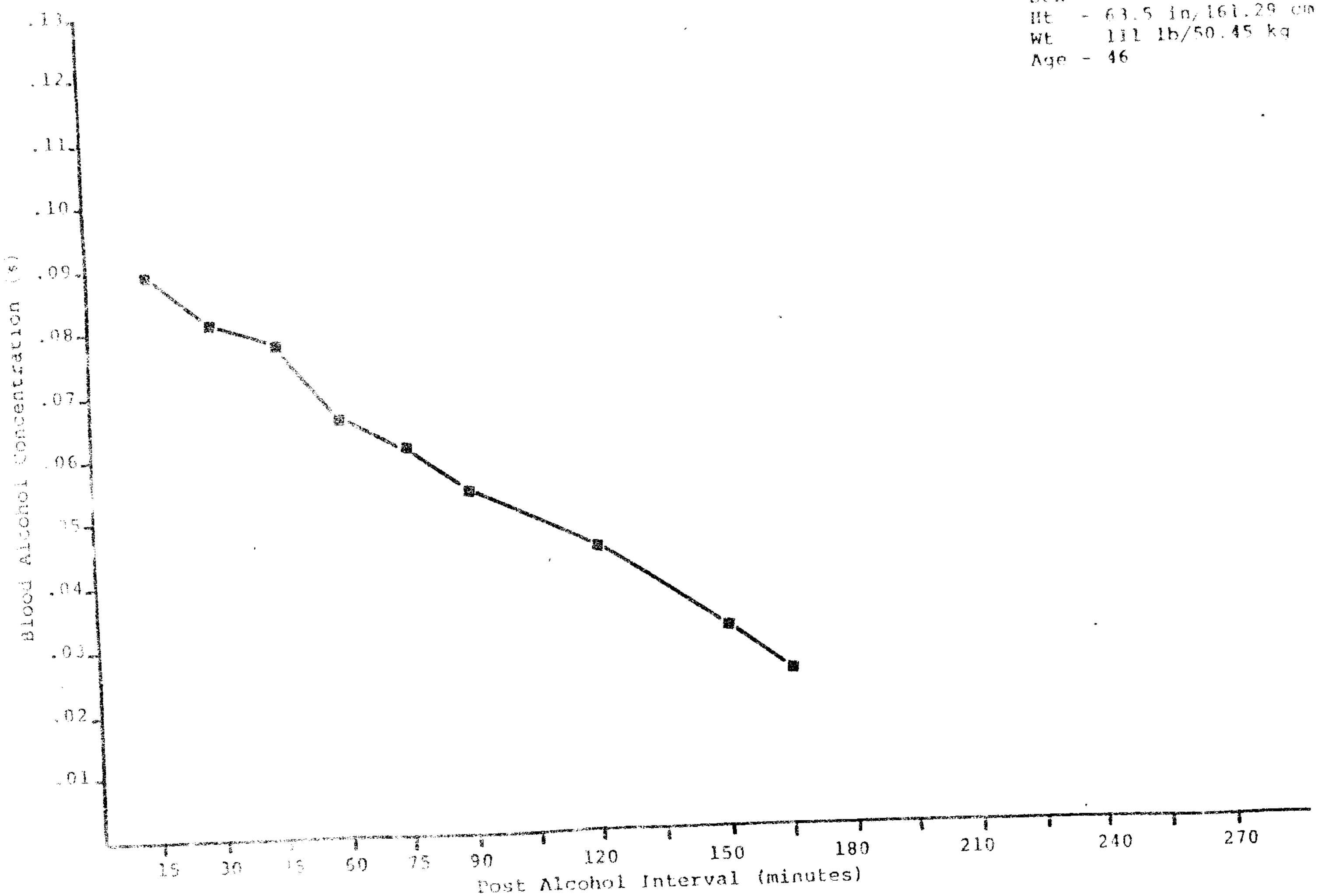
Sex - F
Ht - 64 in/162.56 cm
Wt - 118.5 lb/53.86 kg
Age - 23



Body Fat - BAC
Laboratory Experiment

S# - 54

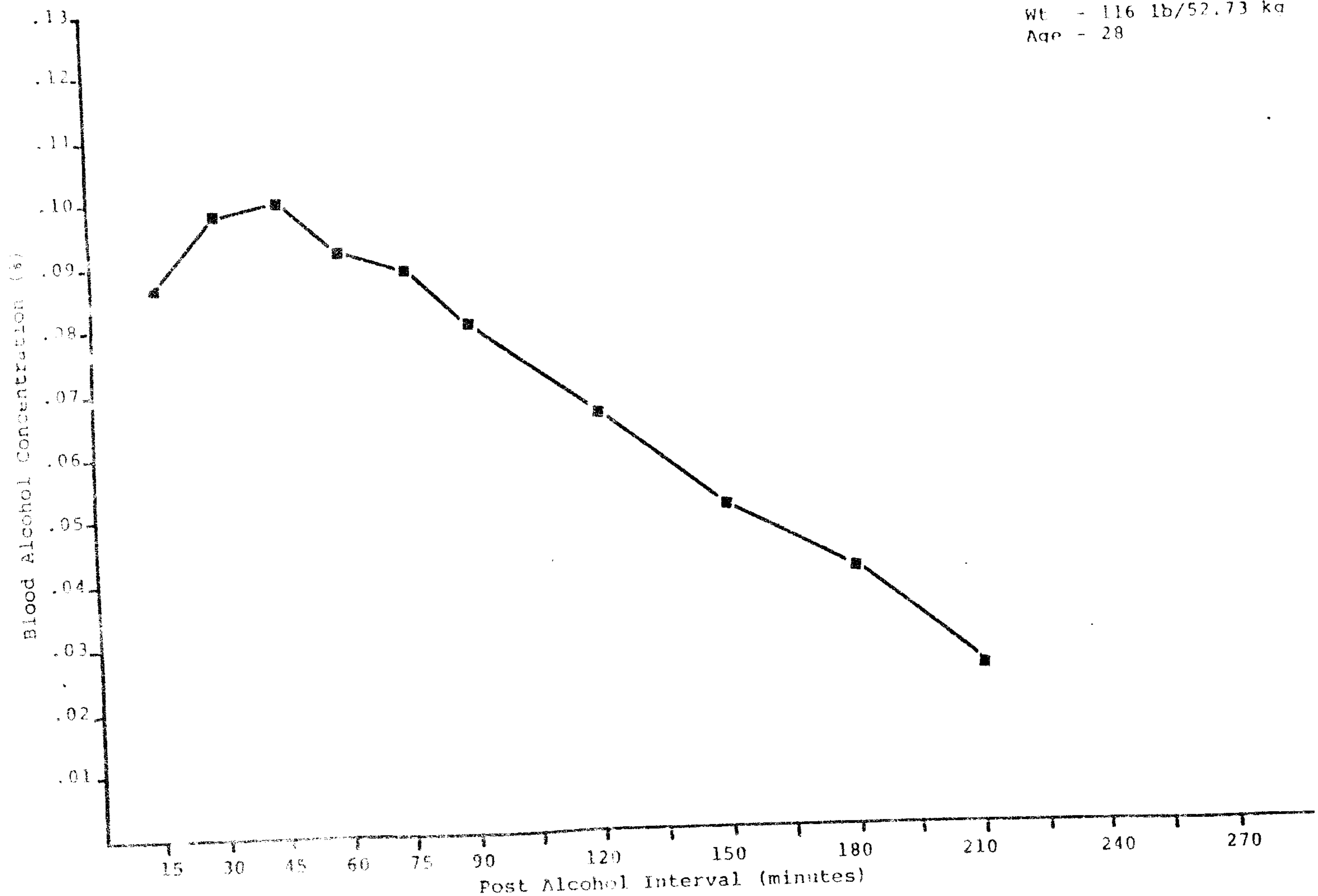
Sex - F
Ht - 63.5 in/161.29 cm
Wt 111 lb/50.45 kg
Age - 46



Body Fat - BAC
Laboratory Experiment

S# - 55

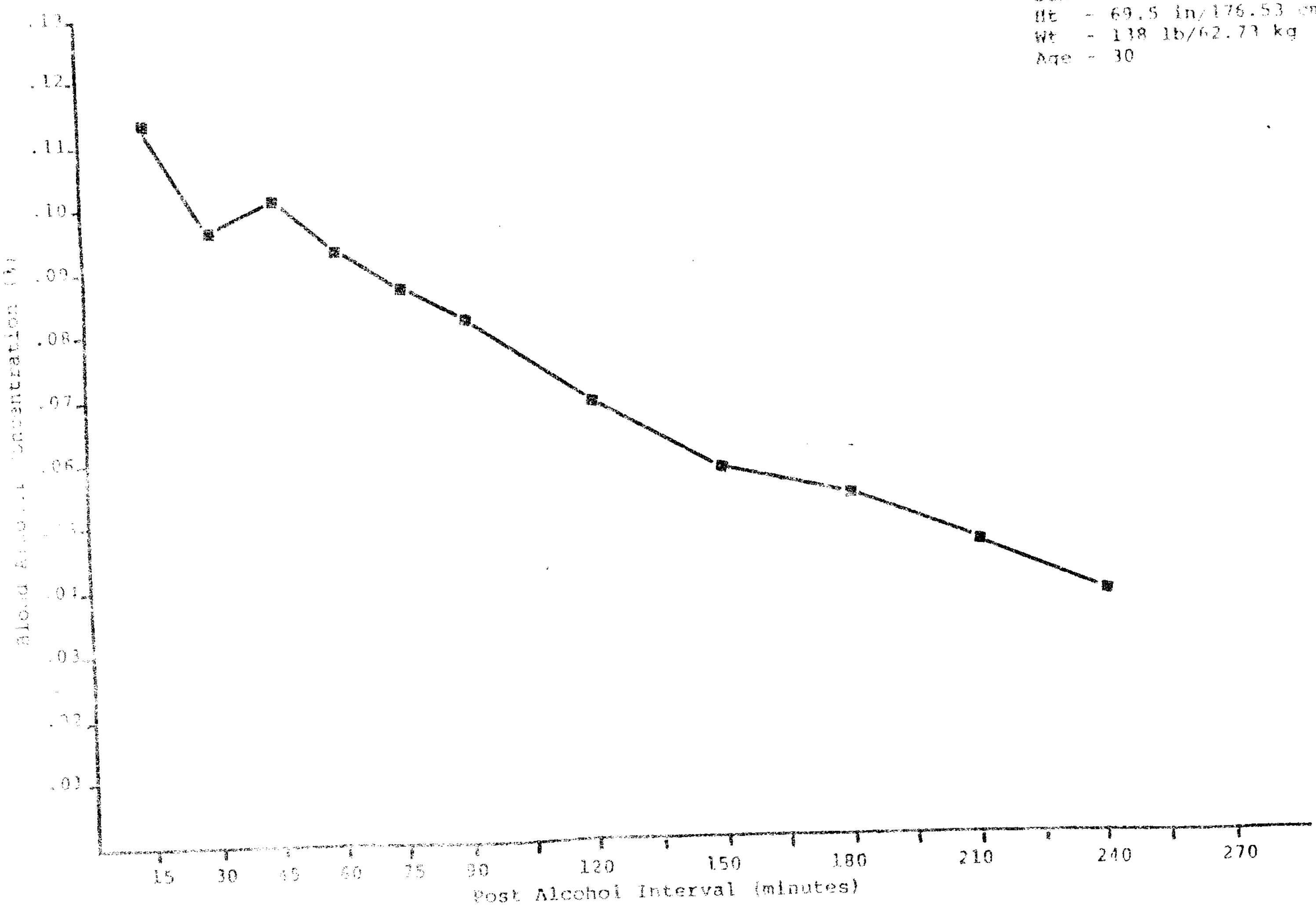
Sex - F
Ht - 69 in/175.26 cm
Wt - 116 lb/52.73 kg
Age - 28



Body Fat - BAC
Laboratory Experiment

S# - 56

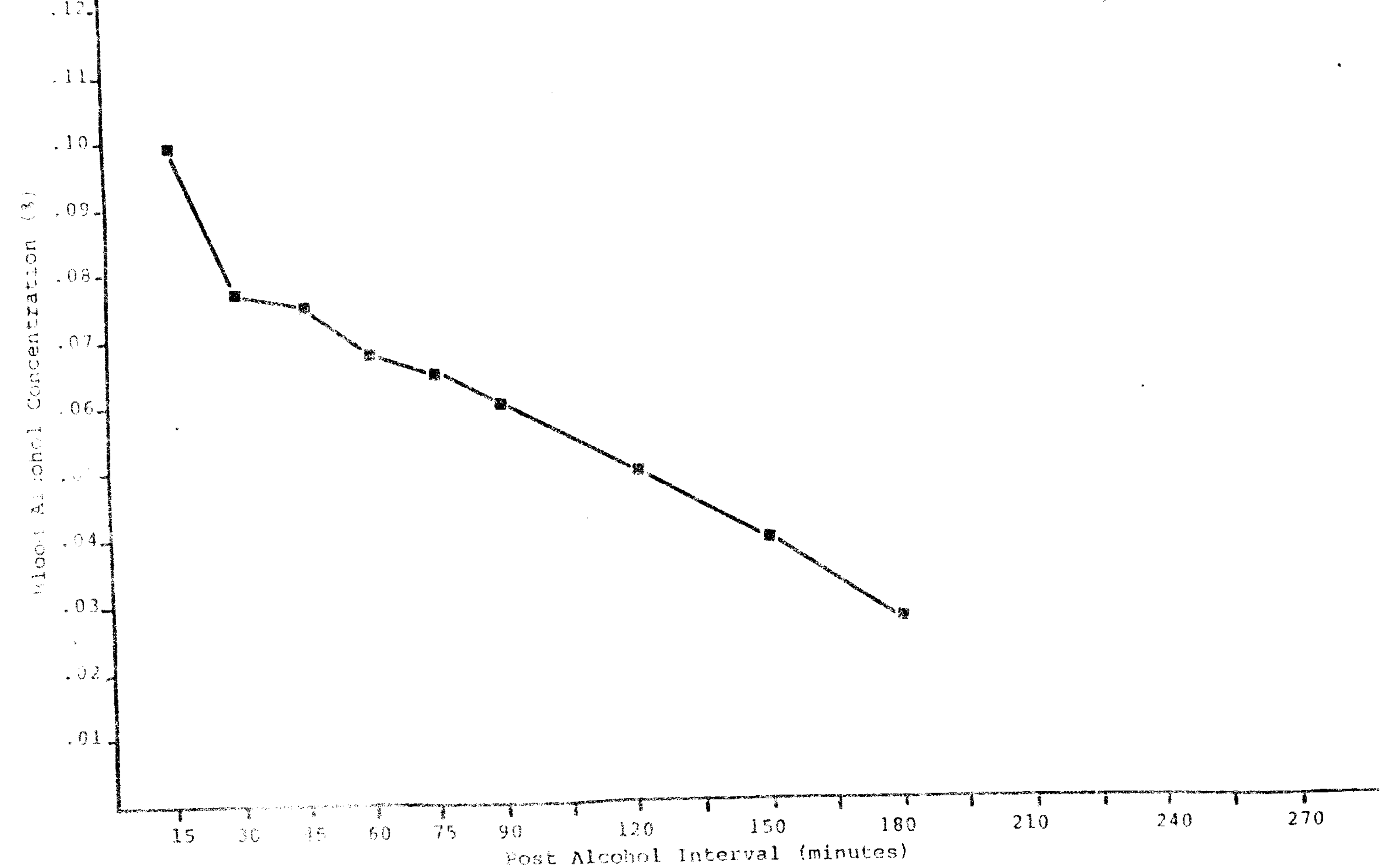
Sex - F
Ht - 69.5 in/176.53 cm
Wt - 138 lb/62.73 kg
Age - 30



Body Fat - BAC
Laboratory Experiment

S# - 57

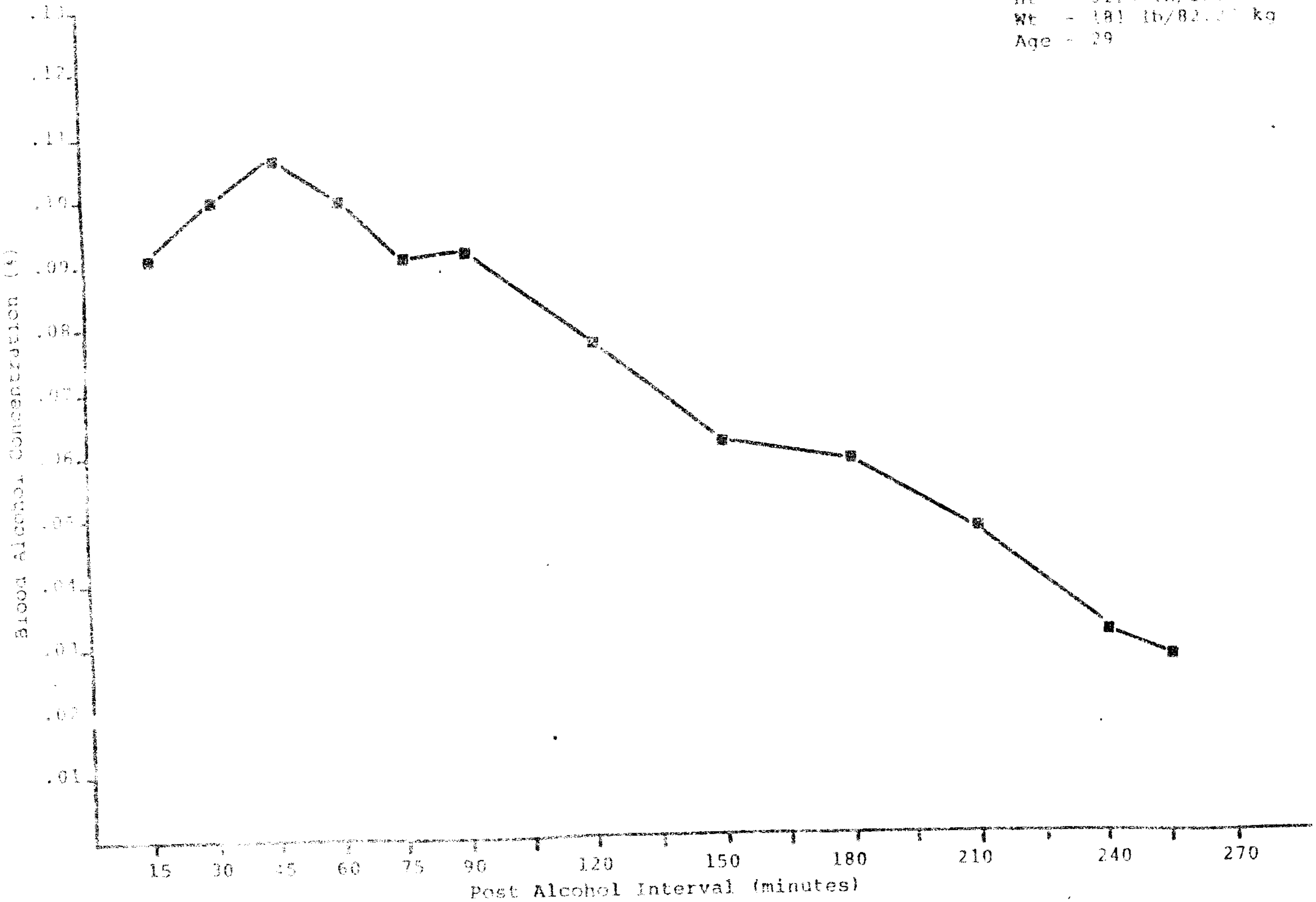
Sex - F
Ht - 56.5 in/143.51 cm
Wt - 80 lb/36.36 kg
Age - 30



Body Fat - BAC
Laboratory Experiment

58

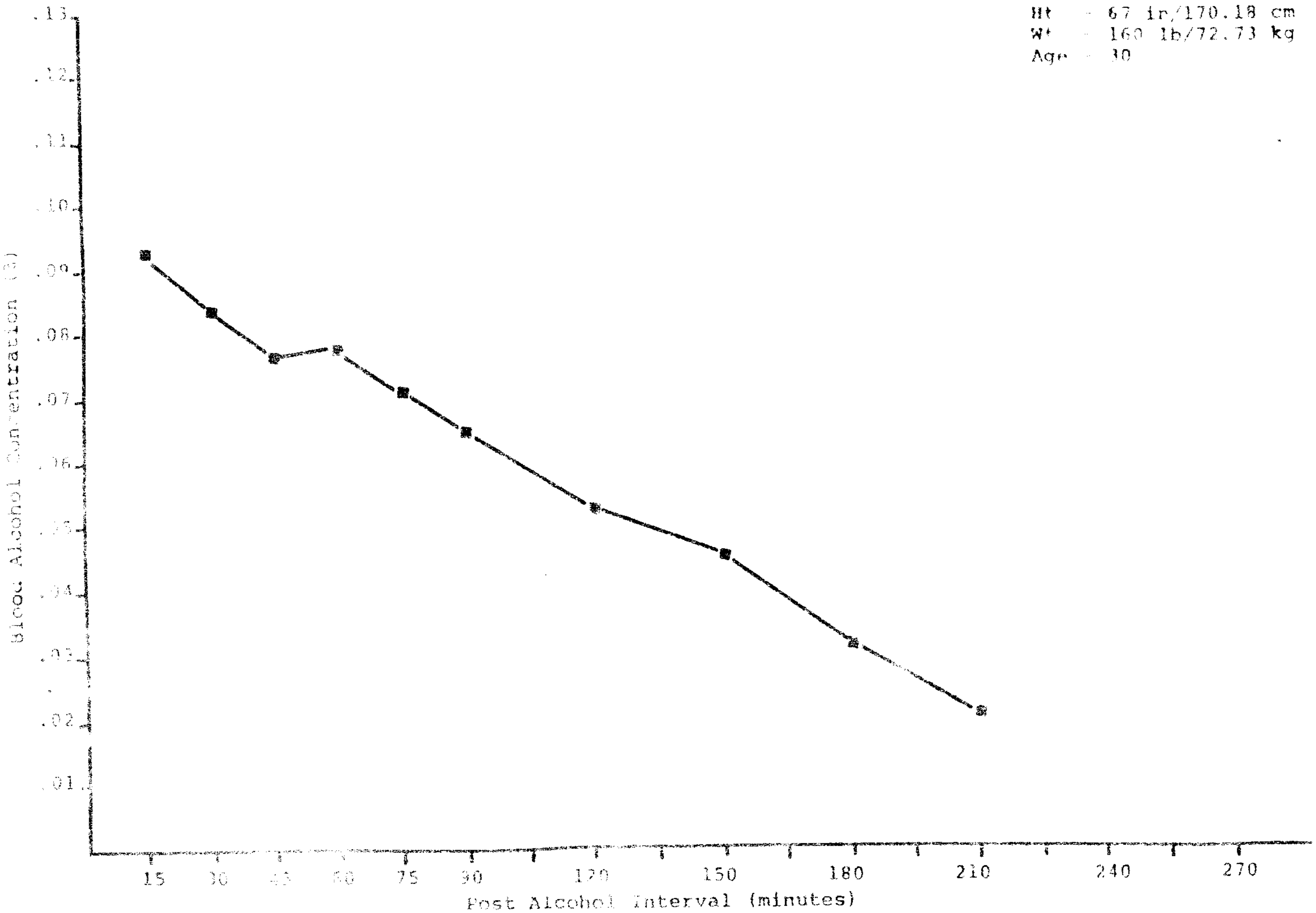
Sex - F
Ht - 61.5 in/156.21 cm
Wt - 181 lb/82.[illegible] kg
Age - 29



Body Fat - BAC
Laboratory Experiment

S# - 59

Sex - F
Ht - 67 in/170.18 cm
Wt - 160 lb/72.73 kg
Age - 30



99