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16. Abstract

Between 1960-1963, a large number of ATC students in training at the FAA Aeronautical Center in Oklahoma City underwent a broad spectrum of biomedical evaluations conducted by the Civil Aeromedical Research Institute (CARI). Approximately 1,270 of these students were evaluated for physical fitness. Included in this evaluation were measurements of height, weight, pulmonary vital capacity, maximum breathing capacity and maximum aerobic working capacity. Principal findings were: 1) physical fitness levels comparable to general population norms of health and 2) expected parameter decrements with age. The age-related decrements in the measured physical parameters generally paralleled the ATC training failure rate. These data will serve as baselines for future evaluations of career ATC personnel in relation to job performance and preventive maintenance of optimum cardiovascular health.

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BIODYNAMIC EVALUATION OF AIR TRAFFIC CONTROL STUDENTS BETWEEN 1960-1963

I. Introduction.

Between 1960–1963, a large number of air traffic control (ATC) students being taught at the FAA Aeronautical Center in Oklahoma City underwent a broad spectrum of biomedical evaluations conducted by the Civil Aeromedical Research Institute (CARI). Since the total spectrum of ATC tasks demands various degrees of both mental and physical fitness in relation to acceptable minimum levels of job performance, it was felt that such initial biomedical measurements could be utilized longitudinally as baselines for subsequent job-related evaluations. This report will confine itself to the biodynamic baseline data gathered at that time.

Approximately 1,270 of the students were evaluated for physical fitness. Adjunct measurements of height, weight, and pulmonary function were also obtained. Because of the non-optional necessity of evaluating up to 60 students per allotted day of testing, because of the limited number of staff on board and because the testing was carried out under essentially "field" conditions at temporary research facilities, an identical battery of parametric measurements was not obtained from each of the 1,331 students eventually processed. Within this context, priority was given to the measurement of maximum aerobic work capacity.

II. Methods.

The general protocol included measurements of unclothed height and weight, pulmonary vital capacity (VC) and maximum breathing capacity (MBC) and maximum aerobic work capacity ($M\dot{V}O_2$). The height and weight were measured to the nearest quarter inch and quarter pound respectively.

The measurements of VC and MBC were obtained using a 13.5 liter "Collins" spirometer and standard spirometry techniques.[1] The measured volumes in both tests were converted to standard conditions of body temperature and pressure saturated (BTPS) and expressed in liters and liters per minute respectively.

The $M\dot{V}O_2$ was measured using several equivalent methods. The most universally accepted method for obtaining this measurement is the standard treadmill test of Balke et al.[2] Because of mandatory stringent scheduling of ATC courses, only one day per ATC class per two-week period was allowed for the $M\dot{V}O_2$ evaluations. Since this necessitated the evaluation of up to 60 ATC students on any given testing day, and since this number could not be processed in one day using the standard treadmill test, other equivalent tests of shorter duration were developed and used for this purpose. The three adjunct tests most frequently used for this purpose were a fifteen-minute running test,[3] a four-grade step test[4] and a four-grade abbreviated treadmill test.[4] The running test was used preferentially for 1,183 of the 1,270 $M\dot{V}O_2$ evaluations because several students could be processed simultaneously in one fifteen-minute period. The $M\dot{V}O_2$ values obtained from all four testing methods were expressed as milliliters of oxygen uptake per minute per kilogram body weight ($\dot{V}O_2$/kg bw). The measured $\dot{V}O_2$ was converted to standard conditions of temperature and pressure dry (STPD).

As opportunity permitted, indirect blood pressure determinations were obtained on some of the students under seated, resting conditions just prior to $M\dot{V}O_2$ testing. The data are based on averages of at least two successive determinations. These were obtained using standard equipment and technique.[5]

III. Results.

Table I presents the frequency distributions of age, height and weight. The average age of the

1,331 students who underwent partial or total testing was 27.7 years. Of the 1,331, approximately 40% were less than 25 years old and approximately 75% were less than 30 years old. The height and weight were obtained on 965 of the students. The average height and weight of this number were 69.7 inches and 162.1 pounds respectively. Figures 1–3 are graphic representations of the data in Table I.

TABLE I. Frequency distributions of age, height and weight of ATC students in the 1960–1963 time period. Age is expressed as the nearest completed year, height to the nearest quarter inch and weight to the nearest quarter pound.

Age Bracket	Average Age	No. of Subjects	% of Total No.	Cumulative % of Total No.	Height and Weight: Avg. Ht. (inches)	Avg. Wt. (pounds)	No. of Subjects
20–24	22.9	561	42.1	42.1	69.5	158.2	411
25–29	26.7	410	30.8	72.9	70.0	163.7	289
30–34	31.3	142	10.7	83.6	69.5	163.9	108
35–39	37.5	109	8.2	91.8	69.4	165.0	82
40–44	41.3	98	7.4	99.2	70.1	172.5	70
45–49	45.8	8	0.6	99.8	68.6	161.5	4
50–54	51.0	2	0.15	99.95	68.5	149.6	1
55 59	55.0	1	0.05	100.00			
ALL	27.7	1331	100.00	100.00	69.7	162.1	965

Table II presents the distributions of VC and MBC versus age. Both the absolute values and the actual/predicted x 100 (act./pred. x 100) values of VC and MBC are tabulated. The predicted values of these two parameters were obtained from the nomograms of Baldwin et al.[1] The numbers of subjects represented by the act./pred. x 100 values of VC and MBC are much less than their respective absolute counterparts. This occurred because the predicted value nomograms are based on age, height and weight and the latter two measurements were not obtained on all of the subjects who underwent VC and MBC testing. The absolute values of these two parameters manifested the expected trend of decrease with age. The act./pred. x 100 values indicated that the mechanical aspects of pulmonary ventilation were grossly normal in this aliquot of subjects. Figures 4–7 present graphic representations of the data in Table II.

TABLE II. Frequency distributions of vital capacity (VC) and maximum breathing capacity (MBC) versus age. Act./Pred. × values of both VC and MRC were calculated according to Baldwin, et al.[1]

Age Bracket	VITAL CAPACITY: Average V.C. L(BTPS)	No. of Subj.	$\frac{\text{Act.}}{\text{Pred.}}$ X 100	No. of Subj.	MAXIMUM BREATHING CAPACITY: Average M.B.C. L/Min. (BTPS)	No. of Subj.	$\frac{\text{Act.}}{\text{Pred.}}$ X 100	No. of Subj.
20–24	4.8	498	107.5	385	158.2	338	114.2	305
25–29	4.7	335	108.5	248	154.7	218	115.9	189
30–34	4.6	120	107.9	96	152.3	87	113.9	79
35–39	4.5	99	106.2	75	149.6	79	116.6	67
40–44	4.3	87	104.5	66	149.4	56	117.8	50
45–49	4.4	7	108.2	3	146.3	2	126.7	2
50–54	3.8	2	105.3	1	133.2	2	116.1	1
55–59	3.0	1			131.8	1		
ALL	4.7	1149	107.5	874	155.0	783	115.3	693

Table III presents the distributions of resting systolic and diastolic blood pressures versus age. The average systolic and diastolic pressures for this relatively small sample of students appear to lie within grossly normal ranges. The average diastolic pressure manifested an expected directional trend of increase with age. No consistent directional trend with age appears obvious for the average systolic pressure. These data are graphically presented in Figure 8.

TABLE III. Frequency distributions of average systolic and diastolic blood pressures versus age.

Age Bracket	Blood Pressure		
	Average Systolic (mm Hg)	Average Diastolic (mm Hg)	No. of Subjects
20–24	125.1	79.8	95
25–29	123.8	81.7	79
30–34	122.3	82.7	24
35–39	125.4	83.6	11
40–44	128.4	86.2	16
45–49	122.0	80.0	2
ALL	124.6	81.4	227

Table IV presents the distribution of $M\dot{V}O_2$ (in terms of maximum $\dot{V}O_2$/kg bw) versus age. The trend of decreasing $M\dot{V}O_2$ with age is apparent and conforms to general expectation. Of the 1,270 students tested, 92.2% were of average fitness according to the Balke rating scale.[2] This rating scale is shown in Table V. The data in Table IV are presented graphically in Figure 9.

TABLE IV. Frequency distribution of average maximum aerobic work capacity ($M\dot{V}O_2$) (in terms of maximum $\dot{V}O_2$/kg bw) versus age.

Age Bracket	Average Maximum $\dot{V}O_2$/kg bw (ml/min/kg)	No. of Subjects	% of Total Number	Cumulative % of Total Number	"Balke" Fitness Rating
20–24	38.6	540	42.5	42.5	Average
25–29	37.6	395	31.1	73.6	Average
30–34	36.5	134	10.6	84.2	Average
35–39	35.9	102	8.0	92.2	Average
40–44	34.6	90	7.1	99.3	Poor
45–49	32.9	6	0.46	99.76	Poor
50–54	34.6	2	0.16	99.92	Poor
55–59	29.7	1	0.08	100.00	Very Poor
ALL	37.5	1270	100.00	100.00	Average

TABLE V. Balke physical fitness rating scale. Mets = multiples of the resting $\dot{V}O_2$/kg bw. Maximum treadmill grade was ascertained using the standard Balke treadmill test[2] in which treadmill velocity is held constant at 3.4 miles per hour and the slope of the treadmill is increased 1% per minute.

Maximum $\dot{V}O_2$/kg bw (ml/min/kg)	Balke Fitness Rating	Mets	Maximum Treadmill Grade (%)	Maximum Distance Run in 15 Min.
<25	Pathological	<7	<8	<0.75
25–30	Very Poor	7–8	8–11	1.0
30–35	Poor	9	11–14	1.25
35–40	Fair or Average	10–11	14–17	1.5
40–45	Good	12	17–20	1.75
45–50	Very Good	13–14	20–23	2.0
50–55	Excellent	15	23–26	2.25
55+	Superior	16+	26+	2.5+

IV. Discusssion and Summary.

The average height of 69.7 inches as measured on 965 ATC students in the 20–55 year age span is slightly greater than the United States population norms[6] of 69.1 inches for the 25–34 year range, 68.5 inches for the 35–44 year range and 68.2 inches for the 45–54 year range. The average weight of 162.1 pounds of this ATC population segment is somewhat less than the reported general population norms [6] of 169 pounds for the 25–34 year range and 170 for the 35–54 year range. These latter two norm weights have been corrected for two pounds of clothing weight.[6] The fact that this ATC group was taller and less heavy than general population norms is probably related to previous military screening since approximately 80% of the ATC students had recent military service.

The VC and MBC of the students generally exceeded general population norms[1] matched for age and body size. Whether purposively or otherwise, general pulmonary health screening was accomplished effectively. The average resting systolic and diastolic blood pressures of the sampled ATC segment lay within the age-matched normal range of the general population.

The average $M\dot{V}O_2$ of these students compared favorably with those of large United States general population as well as military population samples.[2] The decrease of $M\dot{V}O_2$ with age is not unexpected, but would not appear to be desirable since age-matched norms for many other countries exceed those of the United States by significant magnitudes.[7]

During the 1960–1963 period, the Psychology Branch of the CARI performed concomitant aptitude studies on most of the same ATC students covered herein. One of their reports [8] revealed that the satisfactory completion of ATC training was inversely related to age. From a total of 1,210 students represented in their analysis,[8] satisfactory training completion was achieved by 55% of the students in the 21–26 year range, 37% in the 27–32 year range, 26% in the 33–38 year range, 12% in the 39–44 year range and none beyond 45 years of age. This general trend has been corroborated by data from successive ATC student classes up to and including those of the present day. This finding is consistent with the general observation of reduction in psychomotor performance capability with age. It is possible, therefore, that the age-related changes in physical parameters, such as reported here, may reflect the concomitant age-related psychomotor changes and/or may be part of a physical basis for the performance decrease per se. This possibility may be a moot point.

Besides the moot possibility of a beneficial effect on psychomotor performance, the attainment and maintenance of an optimum state of general physical health has a second rationale which is far less moot. Such maintenance is generally accepted as a major deterrent against longitudinal incapacitative chronic diseases. The most serious category of these diseases is that of the cardiovascular system. Because of the high incidence, incapacitation and mortality rates associated with cardiovascular disease,[9] any appreciable deterrence of this disease category in the ATC population should be beneficial to their longitudinal optimum job performance.

The biodynamic data compiled in this report will serve as baselines for the subsequent assessment of longitudinal changes associated with chronological aging and health related aspects of job performance. It is hoped that these data may also be of use in the eventual delineation of improved norms for an optimum state of cardiovascular health and in the detection of the earliest reversible departures from that optimum state.

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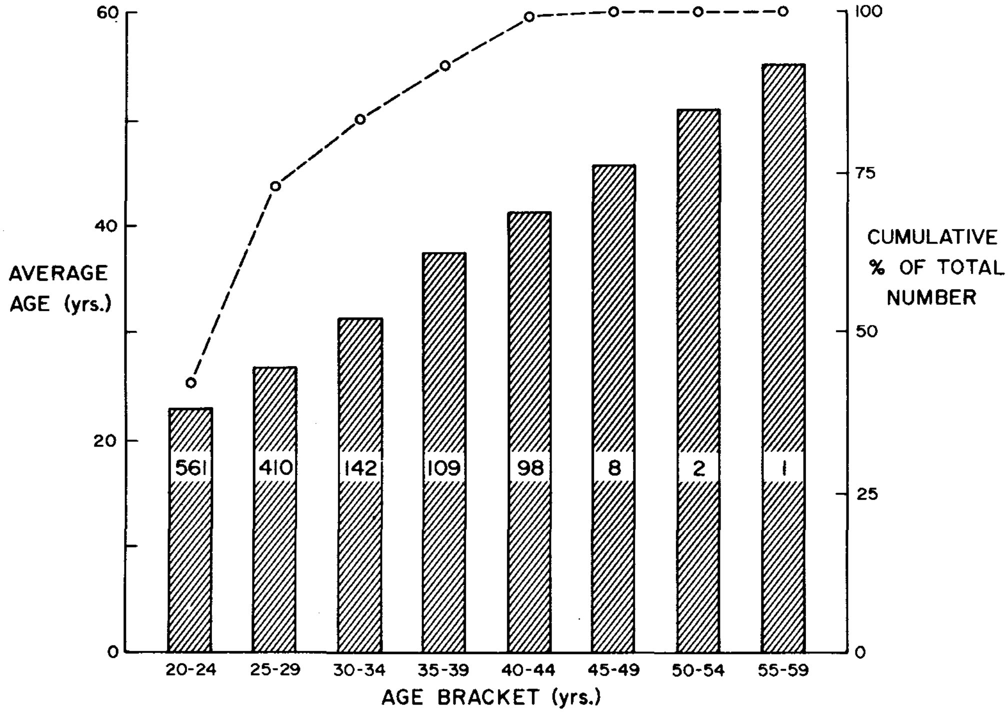

FIGURE 1. Each bar height represents the average age (to the nearest completed year) of the individuals represented by the specified age bracket. The figure within each bar represents the number of individuals in that age bracket. These data represent a total of 1331 individuals. The open circles connected by dashed lines represent the cumulative % of the total number of individuals at each successive age bracket.

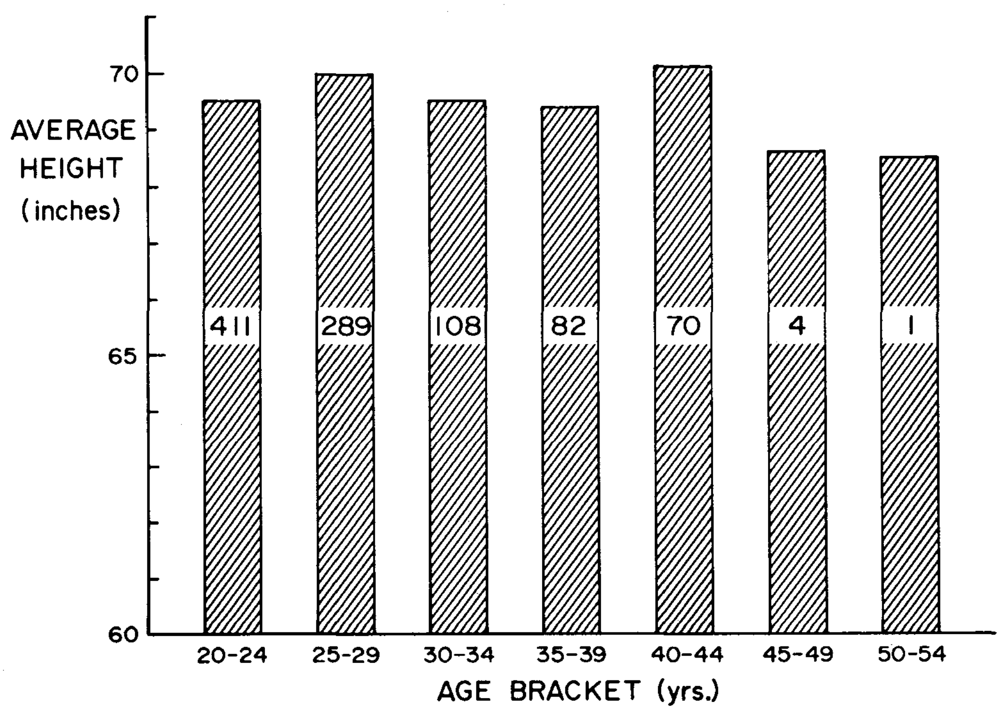

FIGURE 2. Each bar height represents the average height (in inches) of the individuals within the specified age bracket. The figure within each bar is the number of individuals represented by that bar. These data represent a total of 965 individuals.

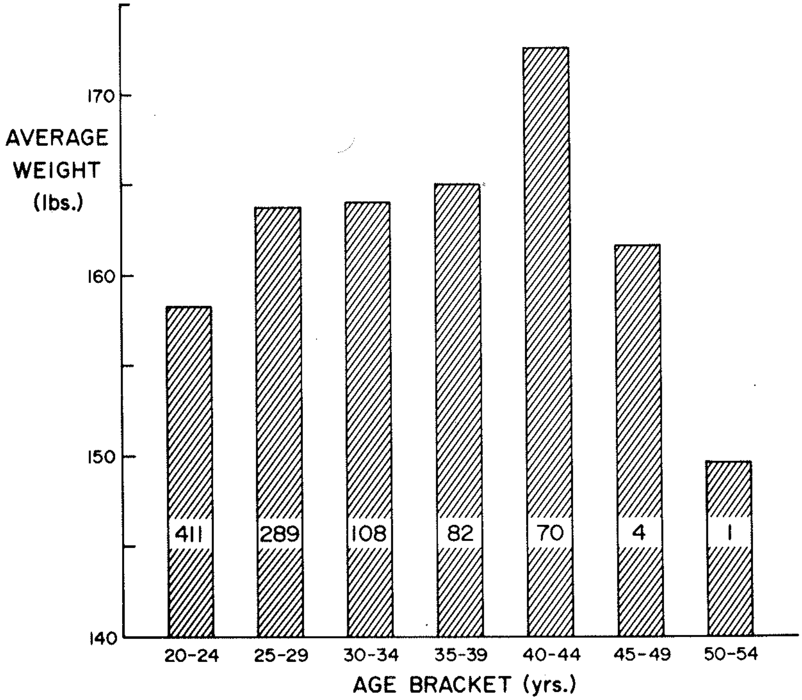

FIGURE 3. Each bar height represents the average weight (in pounds) of the individuals within the specified age bracket. The figure within each bar is the number of individuals represented by that bar. These data represent a total of 965 individuals.

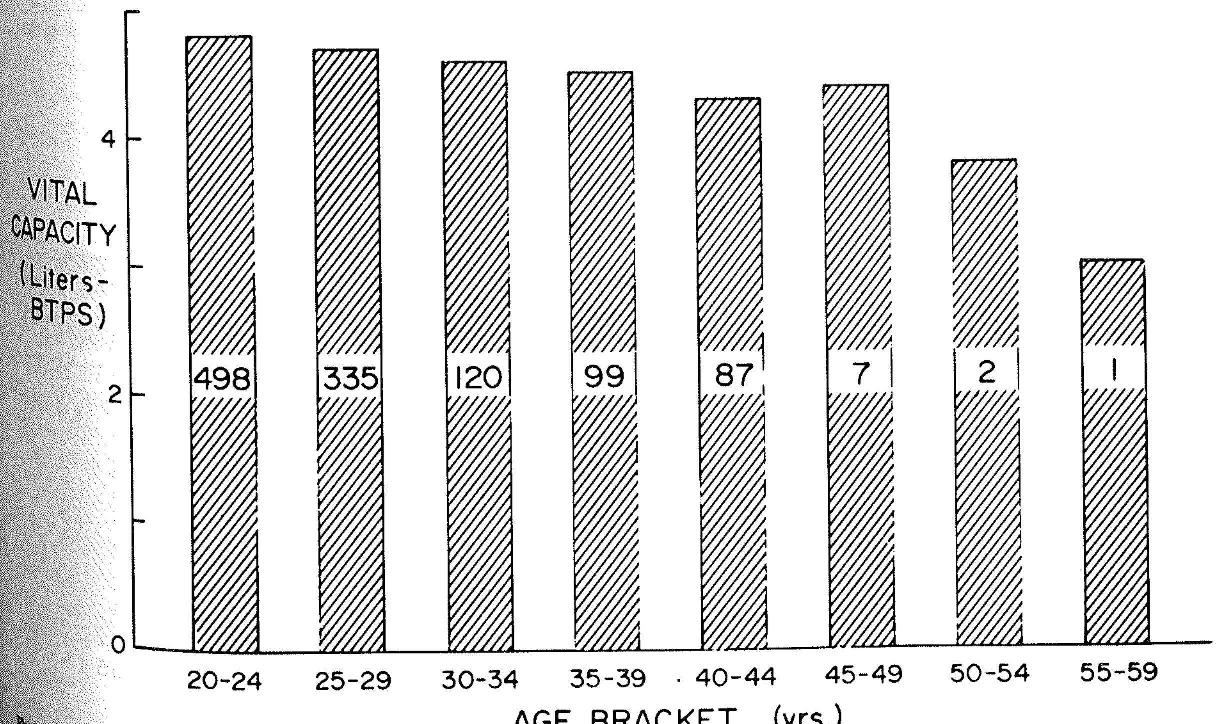

FIGURE 4. Each bar height represents the average vital capacity (in liters—BTPS) of the individuals within the specified age bracket. The figure within each bar is the number of individuals represented by that bar. These data represent a total of 1149 individuals.

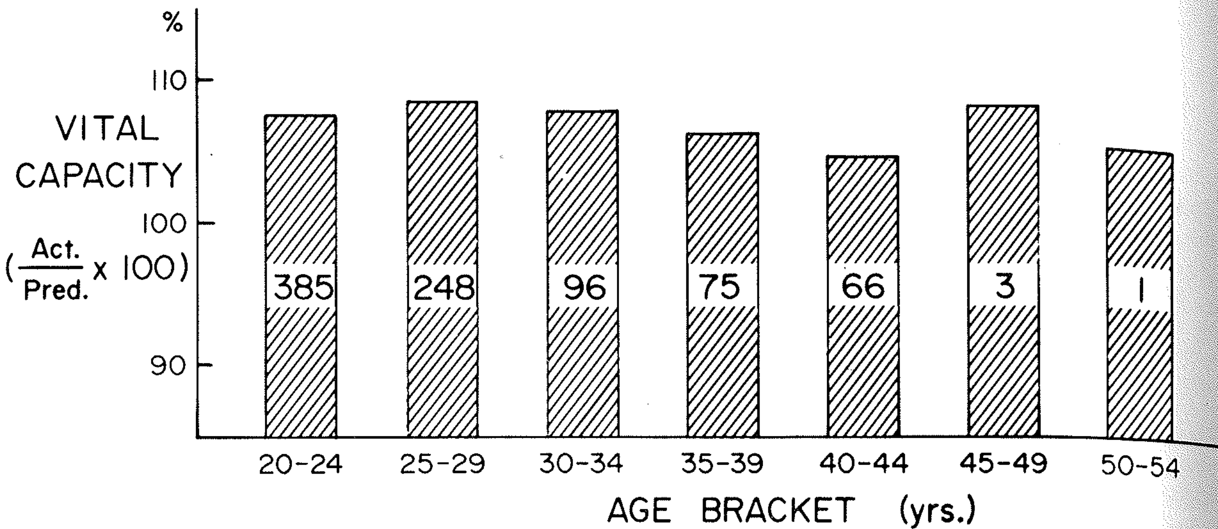

FIGURE 5. Each bar height represents the average Act./Pred. × 100 vital capacity value of the individuals within the specified age bracket. The figure within each bar is the number of individuals represented by that bar. These data represent a total of 874 individuals.

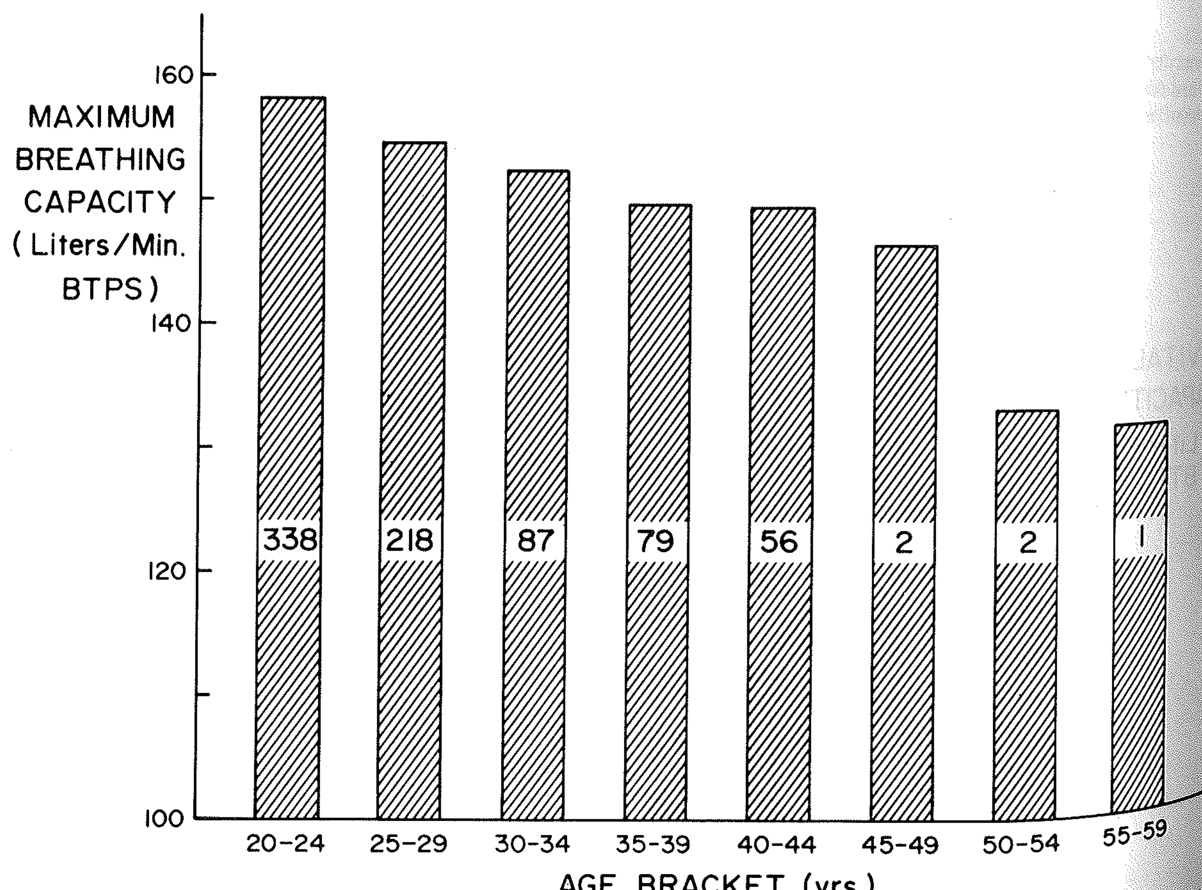

FIGURE 6. Each bar height represents the average maximum breathing capacity (in liters/min.—BTPS) of the individuals within the specified age bracket. The figure within each bar is the number of individuals represented by that bar. These data represent a total of 783 individuals.

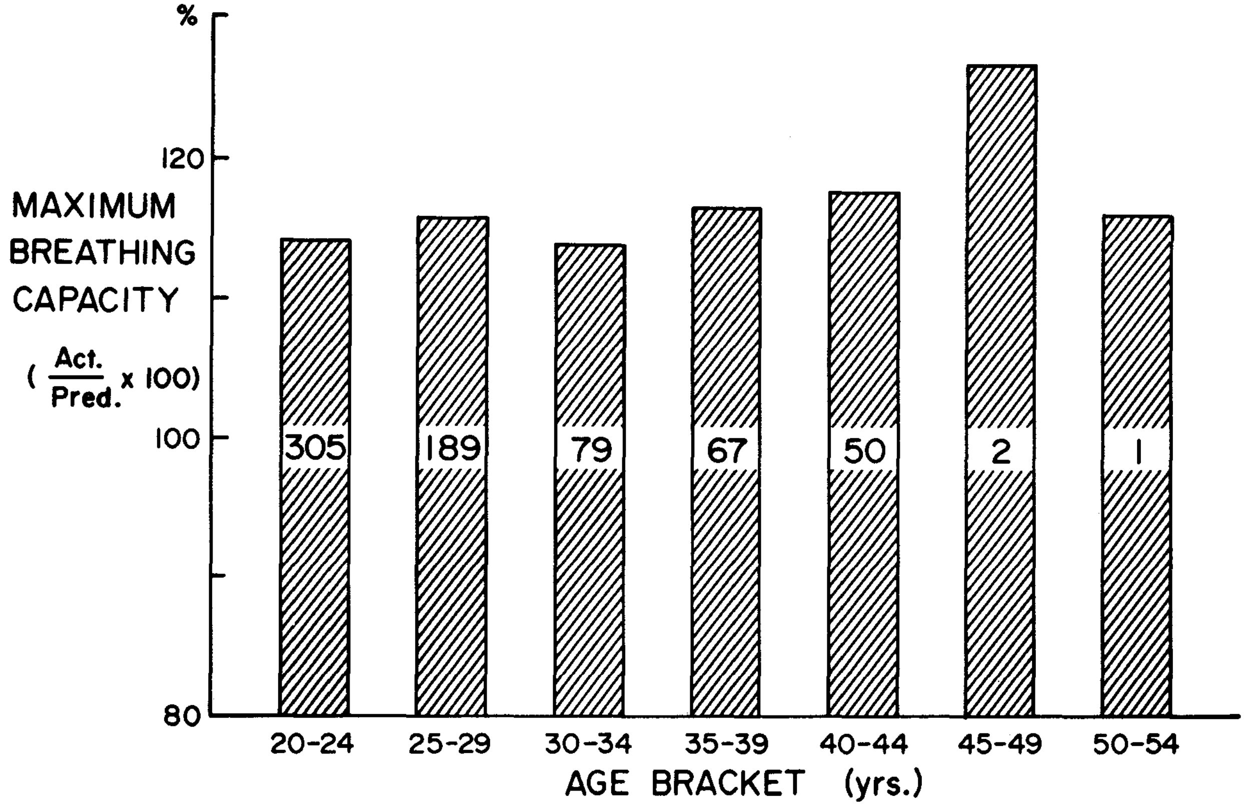

FIGURE 7. Each bar height represents the average Act./Pred. × 100 maximum breathing capacity value of the individuals within the specified age bracket. The figure within each bar is the number of individuals represented by that bar. These data represent a total of 693 individuals.

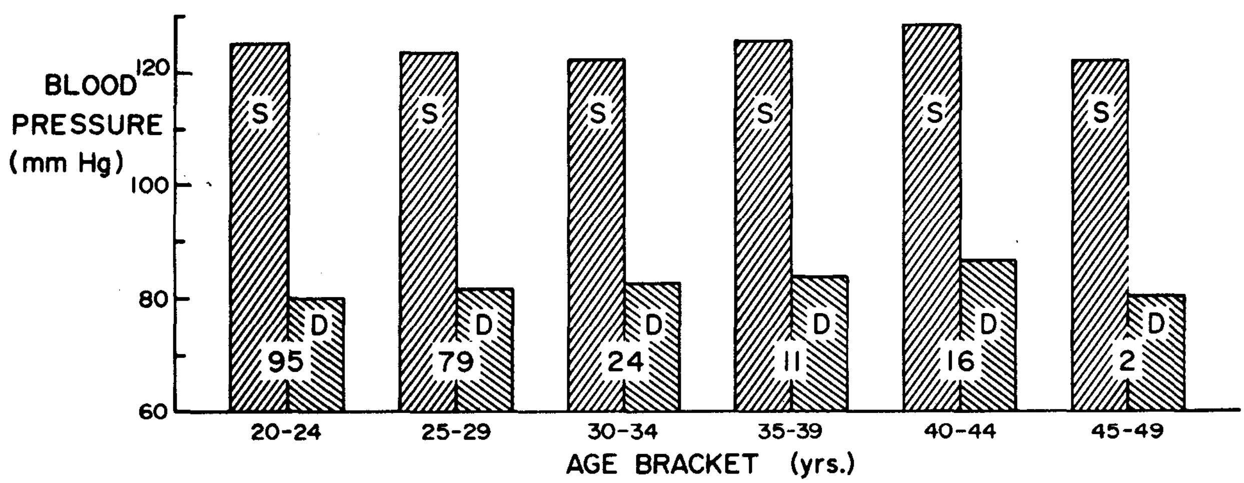

FIGURE 8. Each bar height represents the average systolic (S) and diastolic (D) blood pressure values (in mm Hg) of the individuals within the specified age bracket. The figure within each pair of bars is the number of individuals represented by that bar pair. These data represent a total of 227 individuals.

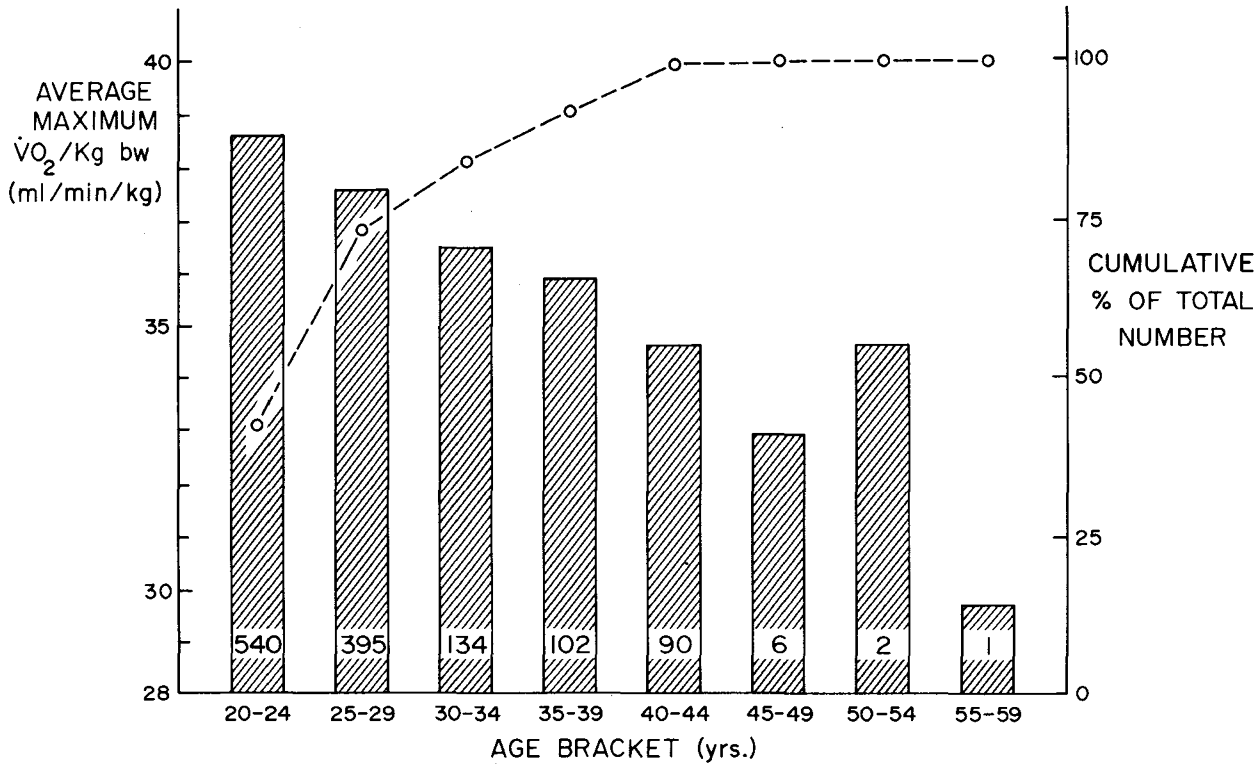

FIGURE 9. Each bar height represents the average maximum aerobic work capacity (MVO_2) (in terms of VO_2/kg bw) of the individuals within the specified age bracket. The figure within each bar is the number of individuals represented by that bar. The open circles connected by dashed lines represent the cumulative % of the total number of individuals at each successive age bracket. These data represent a total of 1270 individuals.

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TABLE 7.—Results of the Paired t Tests for the Pre vs. Post I and Pre vs. Post II Comparisons of the Nystagmic Responses of the Control Group to the Rotatory Stimuli.

Measure	Comparison	Condition				
		Mental Arithmetic		Key Press		Reverie
		Acc	Dec	Acc	Dec	Acc
Displacement	Pre vs. Post I	3.45**	1.07	1.16	0.92	0.98
	Pre vs. Post II	3.94**	1.15	2.06	0.92	0.68
Frequency	Pre vs. Post I	0.81	2.03	2.12	0.83	0.85
	Pre vs. Post II	0.15	0.79	0.66	1.27	0.13
Duration	Pre vs. Post I	0.26	0.78	0.64	0.82	0.44
	Pre vs. Post II	0.62	0.48	1.34	1.17	0.88
Velocity	Pre vs. Post I	0.32	1.83	2.60*	0.64	1.21
	Pre vs. Post II	0.05	1.79	0.24	1.36	0.71

* $p < .05$
** $p < .01$

The Pre-to-Post I declines in nystagmus for the moderate alcohol group were larger than those noted for the control group. All of the significant declines resulting from the accelerations (.05–.001 levels) occurred for the frequency and duration measures in Table 8. The Post II values were very near the Pre levels.

The suppressive effect of alcohol was most evident in the responses of the high alcohol group. With the exception of two of the "peak velocity" measures for the brake decelerations, all of the changes in slow phase displacement, frequency, peak velocity, and duration were statistically significant (.05–.001 levels). Even though there was considerable recovery at the Post II testing session, most of the frequency and duration scores were still significantly below their Pre levels (Table 9).

Thus, alcohol ingestion suppresses the nystagmic response to angular stimuli when the re-

TABLE 8.—Results of the Paired t Tests for the Pre vs. Post I and Pre vs. Post II Comparisons of the Nystagmic Responses of the Moderate Alcohol Group to the Rotatory Stimuli.

Measure	Comparison	Condition				
		Mental Arithmetic		Key Press		Reverie
		Acc	Dec	Acc	Dec	Acc
Displacement	Pre vs. Post I	1.12	1.28	0.31	0.27	1.80
	Pre vs. Post II	1.60	0.57	1.70	1.35	0.89
Frequency	Pre vs. Post I	3.40**	4.12**	2.75*	1.91	2.11
	Pre vs. Post II	0.44	0.75	0.16	0.57	0.45
Duration	Pre vs. Post I	2.79*	3.69**	3.96**	4.89**	3.57**
	Pre vs. Post II	0.94	1.93	1.04	1.90	1.01
Velocity	Pre vs. Post I	0.07	0.93	0.76	2.33*	0.21
	Pre vs. Post II	0.90	0.08	2.71*	3.18*	1.78

* $p < .05$
** $p < .01$
*** $p < .001$