THE THOUSAND AVIATOR STUDY:

SMOKING HISTORY CORRELATES OF SELECTED PHYSIOLOGICAL, BIOCHEMICAL, AND ANTHROPOMETRIC MEASURES

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SUMMARY PAGE

THE PROBLEM

The Pensacola Thousand Aviator Study began in 1940 with the examination of 1056 student aviators and flight instructors on a variety of physiological, psychological, and socioeconomic parameters. Follow-up examinations on the group were conducted in 1951, 1957, and 1963. During the 1963 follow-up, smoking history information on 675 subjects was obtained by questionnaire and confirmed by interview, together with concurrent data from clinical examinations, laboratory tests, anthropometry, and personal history variables. Two smoking variables were created, Cigarette Amount (CA) and Cigarette Years (CY), each on a scale of 1 to 5 points. From the concurrent data, 62 variables were selected for relevance and general interest to be examined in relation to smoking.

FINDINGS

Twenty-four of the 62 variables had significant correlations ($p < .05$) with CA, and 16 showed significant relationships to CY. Findings are related briefly to previous research, and problems of cause-effect isolation are mentioned. It is concluded that results in general support previous findings on smoker-nonsmoker differences. Contributions of the study in delineating areas of research for longitudinal investigation are discussed.

INTRODUCTION

An extensive body of literature has indicated the presence of a definite statistical association between smoking and lung cancer. While some writers (2, 21, 22) have attempted to refute the evidence pointing to this relationship, a far more intense disagreement concerning the cause and effect interpretation of the evidence has raged politely for a number of years. The Advisory Committee to the Surgeon General of the U.S. Public Health Service, in the report Smoking and Health (27), expresses what is probably the majority opinion with respect to this cause-effect controversy. Considering the demonstrated statistical relationship and its internal consistency and coherence with regard to regional and group differences, the committee concludes that smoking is causally linked to the development of lung cancer. Hammond (12) provides additional arguments for the ascription of causality.

A number of investigators, while accepting the statistical significance of the evidence, have questioned the inference of causality. They present the hypothesis that the association is not necessarily causal, but may instead be accounted for by a process in which a predisposition to smoke is genetically or environmentally linked to physiological factors which produce the observed increase in lung cancer. This hypothesis, originally advanced by Fisher (9), has been supported by Eysenck and others (7,8). Still a third possible interpretation, not yet adequately explored, is the acceptance of smoking as a significant cause of lung cancer, while considering that genetic and environmental factors may produce 1) variations in an individual's likelihood of initiating the smoking habit, and 2) differences in type of smoking, degree of tobacco consumption, and ability of the individual to discontinue smoking.

Efforts to resolve this controversy over interpretation have in general centered around attempts to determine if persons who smoke may be fundamentally different in certain ways from those who do not. These efforts have involved the exploration of a variety of physiological, psychological, and socioeconomic dimensions on which smokers and nonsmokers could conceivably differ. Several summaries have attempted to organize the large body of literature on these differences, chief among them being the previously cited Smoking and Health and the overview by Matarazzo and Saslow (23) of the psychological and socioeconomic correlates of smoking behavior.

From these reviews it can be seen that consistent smoker-nonsmoker differences have been demonstrated with respect to a multitude of diverse measures. Also evident, however, is the tangling of cause and effect of smoking within these differences. Division of differences into those that are caused by smoking and those that are causes of variation in smoking behavior is clearly impractical on the basis of present evidence, even if the possibility of circularity of cause-effect is disregarded. In addition, these differences, while significant, are often quite small, and are typically differences of degree rather than kind, with no characteristic always present in one group and always absent in the other. It seems apparent that a great deal more research is required to isolate and describe those factors which distinguish smokers from nonsmokers, and to

determine whether the two groups may represent fundamentally different constitutional or psychological "types."

Data described in this report were obtained during the 1963 follow-up examination in the Pensacola Thousand Aviator Study, a longitudinal investigation begun in 1940 with the examination of 1056 student aviators and flight instructors on a variety of parameters, and continued with follow-ups in 1951, 1957, and 1963. Results of this analysis serve 1) to present findings on variables not previously examined in relation to smoking, 2) as a confirmation of previously established relationships, and 3) to point out areas of research which merit more intensive investigation in longitudinal or prospective examinations such as the Thousand Aviator Study.

PROCEDURE

SUBJECTS AND VARIABLES

During the 1963 follow-up examination smoking history information was obtained by questionnaire and confirmed by interview on 675 surviving members of the original Thousand Aviator group. These members ranged in age from 42 to 62 years, with a mean age of about 47 years; 96 per cent of the population were between 42 and 51 years of age.

Subjects were asked to report the number of cigarettes smoked daily and the number of years that they had smoked cigarettes. Distinct biases were observed in the reporting of cigarette consumption and years, with subjects responding in numbers ending in 0 and 5 and in multiples of 20. Natural divisions and discontinuities in the data were apparent, and two variables, Cigarette Amount (CA) and Cigarette Years (CY), were created on the basis of these divisions, with intervals as indicated in Table I.

Table I

Scale Intervals for Cigarette Amount and Cigarette Years

CA	Scale Value	CY
Nonsmokers*	1	Nonsmokers*
1-19 cigarettes/day	2	1-10 years
20 cigarettes/day	3	11-20 years
21-39 cigarettes/day	4	21-25 years
40 or more cigarettes/day	5	26 or more years

*For this analysis, former smokers (stopped more than one year) and smokers of pipes and cigars only were classified as cigarette nonsmokers.

While the unequal-interval scales and the coding of former smokers and pipe and cigar smokers as cigarette nonsmokers may introduce some error into the data, this error would tend to be in the conservative direction, making obtained relationships underestimates of the true values.

In addition to smoking information, concurrent data were obtained on the subjects from clinical examinations, laboratory tests, anthropometry, and personal history questionnaires. From these data, 62 variables were selected on the basis of relevance and general interest to be examined in relation to smoking history. All laboratory and physical examination data were obtained by standard techniques. Complete descriptions of procedures and methodology and additional information on composition and characteristics of subjects in the study group are given in a previous publication (25).

ANALYSIS OF DATA

Means and standard deviations of all variables were computed, and the intercorrelation matrix obtained. Although each of the 675 examined men underwent nearly all tests and procedures, slight variations in numbers of subjects for each variable arose from scheduling difficulties due to equipment breakdown, and from nonavailability of satisfactory technical records. Correlations are based only on those 600 subjects for whom complete data on all variables were available.

RESULTS AND DISCUSSION

Because of the large amount of data in this study, means, standard deviations, and intercorrelations of the 62 independent variables are not reported here, but are available in an earlier monograph (26). Table II shows proportions of the sample at each of the scale values of CA and CY.

Table II

Proportions of Sample at Scale Values of CA and CY

CA	Scale Value	CY
.315	1	.315
.185	2	.112
.244	3	.199
.151	4	.155
.104	5	.218

The previously mentioned reporting bias is apparent in the table, with almost one quarter of the sample (.35 of all smokers) responding in scale 3 of CA (exactly 20 cigarettes per day). Roughly a third (.315) of the sample were classified as cigarette nonsmokers. Of those so classified, 37 per cent had never smoked, 35 per cent were former smokers who had stopped for more than one year, and 28 per cent smoked pipes and cigars only. Cigarette smokers were homogeneous with respect to inhaling habits, with 94 per cent reporting regular inhaling. It is interesting to note that the percentage of the sample classified as nonsmokers in 1963 is identical to the 31.5 per cent nonsmokers reported by Oberman, Doll, and Graybiel (24) in an analysis of data from the 1957 Thousand Aviator examination.

Tables III, IV, and V present correlations between the CA and CY criteria and the independent variables, with Table III showing variables for which no relationship was present with either criterion, Table IV presenting variables for which correlations with either criterion were significant beyond the .01 level, and Table V giving those variables with significant relationships between the .05 and .01 levels. All significance values presented are two-tailed (nondirectional hypothesis).

Throughout discussion of findings, Cigarette Amount is treated as the principal smoking measure, with Cigarette Years discussed largely on its divergences from CA. The correlation between the two criteria is high (.680), due primarily to the nonsmokers who occupy exactly the same position on both scales, and thus cause the relationship to be spuriously elevated. For this reason, many of the same patterns of relationship are present for both variables, although important differences do occur.

Many of the nonsignificant findings in Table III are consistent with results of previous studies, the most striking divergences being the lack of relationship demonstrated by height (31), weight (4,31,33), bi-iliac diameter (4),and endomorphy (4), and the somewhat surprising lack of correlation with coronary heart disease (5,13). This latter finding may be attributable in part to the difficulty of detecting relationships by correlation when one group comprises only a small percentage of the sample (5.7 per cent diagnosed CHD), and in part to the retrospective nature of the data, since knowledge of a diagnosis of CHD could influence smoking habits.

Other variables in Table III, while not specifically investigated in other studies, might be expected to show relationships on the basis of general tendencies indicated by previous research. Back and abdominal skinfolds, actual weight/ideal weight, percentage of body fat, and the body diameters and circumference variables, while similar to morphological measures previously found to be associated with smoking (4,15,31), fail to attain the criterion of significance used in this study, although several correlations are very close to the .05 level and would have exceeded this level if the easily justified one-tailed significance values had been used. It should also be noted that CY, although a function of age for the population at large, is unrelated to age for the restricted age range considered in this analysis.

Table III

Variables Having Nonsignificant Correlations with Both Criteria*

Variable	CA	CY
1. Age	023[a]	066
2. Systolic blood pressure–supine–basal	039	037
3. Diastolic blood pressure–supine–basal	-003	028
4. Systolic blood pressure–supine–casual	060	050
5. Diastolic blood pressure–supine–casual	-041	022
6. Pulse pressure–supine–basal	063	028
7. Protein-bound iodine	-042	-059
8. Glucose–two hour post-prandial	039	-017
9. Chest diameter (anterior–posterior)	-001	007
10. Uric acid	-024	-021
11. Lipoprotein S_f 12–20[b]	047	051
12. Lipoprotein S_f 20–400[b]	035	-005
13. Atherogenic index[b]	068	047
14. Standing height	065	066
15. Weight	-015	012
16. Back skinfold	-048	-008
17. Abdominal skinfold	-078	-026
18. Chest circumference (midbreath)	-034	-001
19. Chest expansion	024	-017
20. Calf circumference	-038	-041
21. Chest breadth	011	025
22. Bi-iliac diameter	050	041
23. Wrist diameter	078	038
24. Actual weight/ideal weight	-062	-030
25. Per cent body fat	-074	-025
26. Endomorphy	-026	-032
27. Cardiothoracic index	068	041
28. Expiratory reserve volume	-005	-027
29. Coronary heart disease (1–presence, 0–absence)	064	054
Guilford–Zimmerman Temperament Survey scales:		
30. General Activity	-016	-029
31. Ascendance	-012	003
32. Sociability	031	059
33. Objectivity	-025	-079
34. Thoughtfulness	-027	008
35. Masculinity	041	006

*Not significant at .05 level (nondirectional hypothesis): $r_{.05} = \pm .080$

[a]Decimal points omitted.

[b]Values expressed as natural logarithms.

Table IV

Correlations Significant at .01 Level with Either Criterion*

Variable	CA	CY
1. Arcus senilis (1-presence, 0-absence)	097	143
2. Fundus (1-normal to 5-most abnormal)	101	119
3. White blood cell count	290	288
4. Lipoprotein S_f 0-12	138	108
5. Transverse heart diameter/predicted diameter	129	004
6. Heart frontal area	127	055
7. Inspiratory capacity	-211	-148
8. Forced vital capacity	-191	-162
9. Alcohol consumption	271	233
10. Heart rate (resting)	226	213
11. Heart rate (after exercise)	154	204
Guilford-Zimmerman scales:		
12. Restraint	-193	-183
13. Emotional Stability	-113	-115
14. Friendliness	-101	-149
15. Personal Relations	-056	-120

* $r_{.01} = \pm .113$; $r_{.001} = \pm .135$; $r_{.0001} = \pm .159$

Table V

Correlations Significant Between .05 and .01 Level with Either Criterion*

Variable	CA	CY
1. Pulse pressure-sitting-basal	112	052
2. Hematocrit	057	109
3. Serum cholesterol	107	095
4. Arm skinfold	-082	-030
5. Biceps circumference (resting)	-111	-074
6. Ankle diameter	082	033
7. Height/cube root of weight	088	062
8. Ectomorphy	083	079
9. Transverse heart diameter	091	-002
10. Heart frontal area/predicted area	099	047
11. Social status	101	077
12. Ballistocardiogram (0-normal to 3-most abnormal)	051	083

* $r_{.05} = \pm .080$; $r_{.01} = \pm .113$

Consistent with previously reported results are findings in Table IV of reduced pulmonary functions (11,28) and higher heart rate (resting and after exercise) (3,33), while the high association of smoking with alcohol consumption agrees with the majority of previous findings (14,23) but diverges from results found by Damon (4). While smoking has been found to cause an immediate elevation in white blood cell count (17) and levels of lipoprotein S_f 0-12 (16), probably due to an increased discharge of epinephrine and norepinephrine, no long-term effect of smoking on those variables has been demonstrated previously, although the latter findings may be expected from the similarity of the lipid measure to serum cholesterol.

Relationships to smoking for which no previous research was found include an increased prevalence of arcus senilis and a greater frequency of abnormal funduscopic findings among heavier smokers. Likewise, the literature gave no previous indications of the relationship of smoking to greater transverse heart diameter and frontal area (Table V) and to the ratio of these values to that predicted from height and weight, although increased heart size may be attributable to the increased cardiac work and coronary blood flow reported as an immediate effect of cigarette smoking (1). It should be noted that these heart size measurements were correlated only with CA, being essentially unrelated to CY.

Also of note in Table IV are the relationships of smoking to four of the ten scales of the GZTS. The finding that heavier smoking is associated with low Restraint (high "impulsiveness"), low Emotional Stability, low Friendliness (high "belligerence"), and low Personal Relations (high "overcritical") is in a general way similar to previous characterizations of heavier smokers as more "extroverted" (7,8) and more easily angered (33), to certain aspects of Friedman and Rosenman's Type A personality (10), and to smoker-nonsmoker personality differences reported by Heath (14).

With the exception of the heart size measures discussed above, all variables in Table V have been previously examined by others in connection with smoking. The relationship of cholesterol to both CA and CY supports findings of previous studies (4,15,24,33), as does that of pulse pressure (33). Other findings expected on the basis of past research are those of elevated hematocrit (6,19) and a significant tendency for ballistocardiographic abnormalities to be found among heavier smokers (29,32), although the latter relationship has previously been demonstrated only as an acute effect.

In agreement with some studies and in sharp divergence from others is the tendency indicated in this analysis for smokers to be lower in weight for a given height and of a more slender build than nonsmokers, as indicated by relationships to height/cube root of weight and ectomorphy. While this tendency is consistent with results reported by Damon (4) and others (3,15,24), it is in the opposite direction from findings by Thomas (33) and Seltzer (31) that smokers tend to be larger and to show an excess of the heavier body builds when compared to nonsmokers.

Likewise inconsistent with previous research is the finding that heavier smoking tends to be associated with higher social status, as defined by the McGuire-White Index (20). This is divergent from results obtained by Heath (14), Matarazzo and Saslow (23), and other investigators who report an excess of smokers in the lower socioeconomic levels. Such a divergence may be due to an underrepresentation of these lower levels in the Thousand Aviator group, and the obtained relationship could represent merely an association between annual income and number of cigarettes consumed, a finding confirmed by Sackrin and Conover (30).

Such inconsistencies as those above, in which occasional variables show diametrically opposite relationships in two similar studies, may be attributable in part to differences among the groups on which examinations were carried out. A number of previous investigations have employed naturally existing industrial, academic, ethnic, and geographical populations, with resultant decreases of heterogeneity in the samples concerned. While studies on such homogeneous populations hold constant many psychological and socioeconomic influences on criterion variables, results may not be completely generalizable to other populations, and an occasional reversal of findings is not surprising. It should be noted in this connection that the Thousand Aviator Study group was, at the inception of the study in 1940, a highly selected population, all of whose members had passed rigid physical and mental examinations to qualify for flight training. While differences among subjects have increased over the years, the group is still quite homogeneous with respect to many parameters.

Of special note in Tables IV and V are those variables which have significant relationships to CA, but not to CY. In addition to the four heart size measures previously discussed, this situation holds for pulse pressure, arm skinfold, biceps circumference, ankle diameter, height/cube root of weight, and social status. While the differences between correlations of these variables with CA and with CY are in some cases not large, and the connection between variables is not obvious, they do provide some evidence for the existence of a general body size or body weight association with current amount of smoking partly independent of years of smoking, an association which may indicate some controlling influence of current smoking level on body weight. This hypothesis is consistent with the documented appetite-reducing effect of tobacco (17) and agrees with the majority of findings on smoker-nonsmoker differences. It is also supported by results of the 1957 evaluation (24), in which non-smokers gained more weight and had a higher proportion of overweight individuals than did smokers.

CONCLUSIONS

Findings of the study indicate associations between cigarette smoking and many of the variables considered in this analysis, with relationships present in many cases for both amount of smoking and years of smoking. As in the preponderance of previous investigations of this nature, the cause or effect action of smoking and smoking-related variables is unclear. While many, perhaps the majority, of these can be adequately

explained by defining smoking as a causal agent, other associations, such as those of the body size measures, are not easily described in terms of a distinct cause and effect sequence.

An additional complication to the cause-effect isolation involves those correlations which may result from underlying factors common to both members of a demonstrated association. Some support for this common-factor hypothesis is present in this study in the highly significant relationships to smoking of certain of the Guilford-Zimmerman personality variables. It is possible that these personality measures may share with smoking, and other variables, a common causal factor such as some variety of chronic physical or emotional stress, which may in turn be the result of still another underlying factor. Stress as an influence on smoking behavior is discussed at length by McArthur, Waldron, and Dickinson (18).

Results of this analysis indicate, as do those of many other investigations, that smokers and nonsmokers differ on many variables. The relatively small magnitude of these demonstrated differences points clearly to the conclusion that it is not enough to merely delineate those parameters on which the two groups diverge. It is also necessary to determine at least some of the sources of these differences. To date few studies have examined the real possibility of interaction between the smoker, his smoking behavior, and complex cause-effect sequences that contribute to the onset and continuation of smoking in the individual. Broad exploration should be supplemented by research on the role of those interdependent variables which define an individual's behavior pattern in relation to smoking, as opposed to general investigation of group tendencies.

While some relationships in this analysis diverge from those reported previously, results in general support previous findings on smoker-nonsmoker differences. Of special interest in the results are findings on several variables not previously investigated in the smoking context, as well as results on variables previously examined only in relation to the acute or immediate effect of smoking. An additional contribution of this study, and similar studies, lies in the direction which can be given to future research. Results serve not only as additional evidence on the effect of smoking, but also provide a useful indication of those areas which merit more intensive longitudinal examination within the Thousand Aviator Study and similar prospective investigations.

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13. ABSTRACT

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