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16. Abstract

In report number FAA-AM-71-19, an analysis was made of an eight-year interval change in several indicators of coronary heart disease (CHD) susceptibility as measured on 475 male air traffic control (ATC) personnel. The initial measurements were obtained from these personnel as ATC students in 1960-1963 and the subsequent data were obtained eight years later from their current aeromedical certification records. This analysis revealed a general trend of advancing relative susceptibility to CHD with age and obesity. Sample sizes (in age by obesity cells) were frequently too small to warrant any statement of significance for this general trend.

As a logical followup, an analysis of similar data from 23,826 male ATC personnel was accomplished. The data were obtained from current aeromedical certification records in January 1971. The distributions of resting blood pressure (BP), resting heart rate (HR) and the 400 pathology code frequency were compiled in age versus Framingham relative weight index (FRWI) tables. Obesity was defined as a minimum FRWI of 120.0%. Substantiating earlier findings, all parameters generally increased with age and obesity. These findings are directly relevant to the mass aeromedical screening, early detection, susceptibility reversal and preventive aspects of CHD.

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THE USE OF SIMPLE INDICATORS FOR DETECTING POTENTIAL CORONARY HEART DISEASE SUSCEPTIBILITY IN THE AIR TRAFFIC CONTROLLER POPULATION

I. Introduction.

According to the most recent epidemiological statistics, diseases of the cardiovascular system caused 54.1% of all deaths in the United States.[1] Arteriosclerotic heart disease (including coronary heart disease) caused 31.0% of all deaths in the United States.[1] In a 1960–1962 national survey of heart disease prevalence, coronary heart disease (CHD) was found in 5.0% of all adults in the age range of 18–79 years.[1] Furthermore, the presence of silent CHD in the general population is amply documented by clinical[2,3] as well as postmortem studies.[4-6] There is also ample documentation of a surprising amount of early silent CHD in people under 30 years of age.[7-12] According to a recent estimate,[13] silent CHD is present in a minimum of 5.0% of United States males over 35 years of age. A recent study[14] has reviewed the manifold positive evidences relating silent CHD to sudden incapacitation and/or sudden death. Based on the first 14 of 20 years experience, the Framingham Heart Study (FHS) has reported that 57.8% of the 102 male and 38.9% of the 18 female CHD deaths observed were sudden in nature.[15] In this same study, sudden CHD death was defined as "sudden and unexpected collapse and death within one hour (but ordinarily in a matter of minutes) in apparently well persons." In view of the unexpectedness of 65.0% of these 120 CHD deaths, and the absence of a prior definite CHD diagnosis in 62.8% of the 78 unexpected deaths, this study[15] strongly concluded that "the only road to a substantial reduction in premature CHD mortality is the prevention of CHD." Despite the prior absence of a definite CHD diagnosis, 80% of the victims of sudden, unexpected CHD death had previously manifested CHD susceptibility in one or more of the FHS coronary profile parameters.[15]

In a recent congressional hearing, the Federal Air Surgeon reemphasized the role of medical vigilance in the detection of silent or overt forms of CHD in the airman population with especial concern regarding the facet of sudden and unpredictable incapacitation.[16] One basis for this continued concern is the fact that, in the 1963–1970 period, 52.0% of the reconsidered actions by the Federal Air Surgeon were directly related to cardiovascular pathology.[17]

As of December 31, 1970, the active airman population consisted of approximately 727,000 persons.[17] Taking into account the biennial examination of third class airmen, the FAA conducted the medical certification examination of 444,000 airmen in 1970. It appears reasonable to assume that the repetitively examined airman population may have less silent CHD than the general population and that a maximum estimate for this particular condition in the airman population would be less than 5.0%.[13] One possible way of detecting this maximum 5.0% aliquot would be the comprehensive cardiological examination of the 444,000 airmen in one year. One hundred dollars would appear to be a conservative cost estimate for a comprehensive cardiological examination. Although strong in diagnostic certainty, this solution for detecting the maximum 5.0% CHD aliquot, at a cost of approximately 44.4 million dollars per year, would be economically inefficient. Other solutions have been and continue to be sought. This report presents and explores one such possible solution in the specific context of the air traffic controller (ATC) segment of the airman population. A similar report focused on the third class airmen is currently in preparation.

In a previous report,[18] an analysis was made of an eight-year interval change in several FHS indicators of CHD susceptibility as measured on

475 male ATC personnel. The initial measurements were obtained from these personnel as ATC students in 1960–1963 and the subsequent data were obtained eight years later from their current aeromedical certification records. The distribution of each of the parameters used was compiled in an age versus Framingham relative weight index (FRWI) table. The FRWI was used as a measure of obesity. In accordance with the FHS, frank obesity was defined as a minimum FRWI of 120.0%.[19] The distributions of the 1960–1963 data revealed a general trend of parametric increase with age and FRWI. This is consistent with the FHS report of relatively greater CHD susceptibility with increased age and obesity.[19] The distributions of the eight-year interval data revealed the same general trend of increase with age and FRWI. Moreover, an additional shift in the distributions of all the parameters occurred which resulted in an increased concentration in the older/obese categories. This shift was interpreted as a trend of advancing relative CHD susceptibility over the eight-year period. On the assumption that the FHS findings are generally correct, one logical initial focus for comprehensive cardiological examination for CHD should be the oldest/most obese individuals in whom the adjunct FHS parameters were most indicative of the highest relative CHD susceptibility. This approach could become a quite useful adjunct for initial CHD screening of large segments of the airman population[18] at no additional expense to the FAA. One such segment is comprised of approximately 23,000 ATC personnel. In order to seek corroboration of the earlier findings[18] in support of the initial CHD screening possibility, an analysis of similar data from 23,826 male ATC personnel was undertaken.

II. Methods.

A. *1971 Data.* All data were obtained from the active aeromedical certification records in January 1971. Age was expressed as the nearest completed year on the day of the aeromedical certification examination. Height (in inches) and weight (in pounds) are stated rather than measured data. Both of these parameters are vulnerable to errors of stated-type data. Where discovered and confirmed, height errors were corrected. Regarding stated weight, two comprehensive studies[20,21] have reported that heavy men tend to underestimate their weights while light ones tend to overestimate theirs. In this report, the uncorrected stated weights were used as the best available data. The effect of possible errors in stated height and weight on the screening value of the FRWI will be treated in the discussion section of this report. A separate report concerning height and weight errors in aeromedical certification data is currently in preparation.

The resting systolic and diastolic blood pressures (SBP and DBP) were measured using standard medical procedures as prescribed in the FAA Guide for Aviation Medical Examiners. In accordance with this same Guide, the resting heart rate (HR) is determined with the individual relaxed in a sitting position.

The 1965 revised pathology codes of the aviation medical service list all cardiovascular pathology under the 400 series. Once documented and coded, critical items in this series are permanently retained in the individual's medical certification file. Non-critical items may be found in the individual's current file, only if they are currently present. In this analysis, no distinction was made between critical and non-critical code items. However, it appears reasonable to assume that the presence of any 400 series item would generally confer a greater relative cardiovascular susceptibility than its absence.

B. *Age Versus FRWI Tables.* The general rationale of this table format has been presented in a previous report.[18] The FHS rationale and formula for the calculation of the FRWI have been reported previously.[22] The commensurate regression formula, as estimated from the male height and weight data of the 1960–1962 National Health Survey, was virtually identical.[23] An FRWI of 100.0% indicates that the weight of the individual is equal to the median weight of the FHS males of his identical height at the 1950 inception of the FHS.[22] An FRWI of 120.0% or greater indicates frank obesity.[19] For the purposes of this analysis, five categories each of FRWI and age were used in each age versus FRWI table.

III. Results.

Tables 1 and 2 present the age versus FRWI tabulations of mean SBP and mean DBP respectively. In the All FRWIs and All Ages columns of both tables an increase in both SBP and DBP with increasing age and obesity are quite apparent. That age and obesity may be acting independently on the SBP and DBP is strongly suggested by the same pattern of increase within each of the age and FRWI segments. The summary tables of nine major population samplings of age versus blood pressure were examined in relevance to the All FRWIs data columns of Tables 1 and 2. Compared across age groups alone, the SBP and DBP values in Tables 1 and 2 were greater than those in two of these studies [21] and less than those in the remaining seven.[21 24 25] In one of these studies [21] based on data from 235,000 males, a single-table summary of age versus height and weight categories for resting SBP and DBP was compiled. Mathematical conversion of these height and weight data to FRWI equivalents for a subsequent comparison with equivalent age and FRWI categories in Tables 1 and 2 was accomplished. Compared on this basis, all SBP and DBP values in Tables 1 and 2 were greater than

TABLE. 1. Tabulation of Mean SBP Versus Age and FRWI Categories. Each table cell contains the mean SBP value (in mm Hg), the standard error of the mean (± mm Hg) and in parentheses, the number of data used in their calculation.

FRWI (%)	AGE (yrs.)				
	<30	30–39	40–49	> 50	All Ages
<100.0	120.7 ±0.14 (5487)	121.1 ±0.16 (4935)	123.7 ±0.27 (2086)	127.8 ±0.46 (809)	121.8 ±0.11 (13,317)
100.0–119.9	125.1 ±0.19 (2861)	125.4 ±0.18 (4009)	128.2 ±0.28 (1927)	131.0 ±0.55 (760)	126.3 ±0.11 (9,557)
<120.0	122.2 ±0.08 (8348)	123.0 ±0.12 (8944)	125.9 ±0.19 (4013)	129.3 ±0.35 (1589)	123.7 ±0.07 (22,874)
≧ 120.0	130.9 ±0.61 (294)	131.3 ±0.55 (400)	133.1 ±1.11 (194)	136.2 ±1.81 (64)	131.9 ±0.39 (952)
All FRWIs	122.5 ±0.12 (8642)	123.4 ±0.12 (9344)	126.2 ±0.20 (4207)	129.6 ±0.33 (1633)	124.0 ±0.08 (23,826)

TABLE 2. Tabulation of Mean DBP Versus Age and FRWI Categories. Each table cell contains the mean DBP (in mm Hg), the standard error of the mean (± mm Hg) and in parentheses the number of data used in their calculation.

FRWI (%)	AGE (yrs.)				
	<30	30–39	40–49	> 50	All Ages
<100.0	73.7 ±0.11 (5487)	75.2 ±0.12 (4935)	77.2 ±0.18 (2086)	78.7 ±0.30 (809)	75.1 ±0.06 (13,317)
100.0–119.9	76.7 ±0.15 (2861)	78.4 ±0.13 (4009)	80.6 ±0.20 (1927)	81.4 ±0.31 (760)	78.6 ±0.09 (9,557)
<120.0	74.7 ±0.09 (8348)	76.6 ±0.08 (8944)	78.9 ±0.13 (4013)	80.0 ±0.22 (1589)	76.5 ±0.05 (22,874)
≧ 120.0	81.5 ±0.46 (294)	82.6 ±0.41 (400)	84.2 ±0.66 (194)	84.3 ±1.08 (64)	82.6 ±0.28 (952)
All FRWIs	74.9 ±0.09 (8642)	76.9 ±0.09 (9344)	79.1 ±0.12 (4207)	80.1 ±0.21 (1633)	76.8 ±0.04 (23,826)

those of the compared population study.[21] Per se, none of the SBP and DBP values in Tables 1 and 2 are considered to be medically abnormal.[21 24 25] The points of salient interest in Tables 1 and 2 are the increase in SBP and DBP with both age and obesity, and the concentration of the higher blood pressure values in the combined older/obese categories.

Table 3 presents the age versus FRWI tabulation of mean resting HR values. Per se, none of the HR values in this table are considered to be medically abnormal.[24] In the All Ages and All FRWIs columns, an increase in HR with increasing age and obesity is apparent, although the increments of HR increase in the latter column are appreciably small. With few exceptions a pattern of HR increase within each segmental age and FRWI category is present, again suggesting the possibility that age and obesity may be acting independently on the resting HR.

Table 4 presents the age versus FRWI tabulation of the 400 pathology code % prevalence. The parenthesized value in each table cell represents the % prevalence of the 400 pathology code.

TABLE 3. Tabulation of Mean Resting HR Versus Age and FRWI Categories. Each table cell contains the mean resting HR (in beats per minute), the standard error of the mean (± beats per minute) and in parentheses, the number of data used in their calculation.

FRWI (%)	AGE (yrs.)				
	<30	30–39	40–49	> 50	All Ages
<100.0	73.7 ±0.12 (5487)	73.9 ±0.12 (4935)	74.2 ±0.18 (2086)	74.4 ±0.30 (809)	73.9 ±0.07 (13,317)
100.0–119.9	74.3 ±0.15 (2861)	74.5 ±0.13 (4009)	74.7 ±0.19 (1927)	75.0 ±0.29 (760)	74.5 ±0.08 (9,557)
<120.0	73.9 ±0.09 (8348)	74.2 ±0.08 (8944)	74.5 ±0.14 (4013)	74.6 ±0.21 (1589)	74.1 ±0.05 (22,874)
≧120.0	76.7 ±0.54 (294)	76.8 ±0.44, (400)	76.6 ±0.66 (194)	74.2 ±0.42 (64)	76.5 ±0.29 (952)
All FRWIs	74.0 ±0.09 (8642)	74.3 ±0.08 (9344)	74.5 ±0.13 (4207)	74.6 ±0.21 (1633)	74.2 ±0.05 (23,826)

In the All Ages and All FRWIs columns of this table an increase in 400 pathology code % prevalence with increasing age and obesity is clearly manifested. That obesity and age may be acting independently on the 400 pathology code % prevalence is strongly suggested by the same pattern of increase within each age and FRWI segment. The increased concentration of this parameter in the combined older/obese categories is of primary interest.

IV. Discussion.

In general corroboration of the findings presented in a previous report,[18] the trends of the parameters presented here in similar age versus FRWI tables support the presence of a relatively increasing CHD susceptibility with age and obesity in the entire ATC population. Further, a general concentration of the most elevated parametric values reflecting the highest relative susceptibility to CHD occurs in the combined older/obese categories.

Although all the SBP and DBP values in Tables 1 and 2 appear to be well below the threshold values for marked CHD susceptibility,[26] a general increase with age and obesity is apparent with a concentration of the higher values in the combined older/obese categories. Although the highest SBP and DBP values in the combined older/obese categories do not exceed the threshold values for marked CHD susceptibility,[26] it appears quite reasonable to assume that a greater relative CHD susceptibility exists in these categories than in the younger/thinner counterpart categories manifesting the lower SBP and DBP values. Over its 20 years of experience, the FHS has definitely established the prospective relationship of initial hypertensive levels of blood pressure (>160 mm Hg SBP and/or >95 mm Hg DBP) to the subsequent development of overt CHD.[15 27 28] This relationship is a continuum which includes non-hypertensive levels of blood pressure.[28] As specifically stated in this particuar FHS report [28] based on the first 14 of its 20 years of data: "Risk of every manifestation of CHD including angina, coronary insufficiency,

TABLE 4. Tabulation of the 400 Pathology Code % Prevalence Versus Age and FRWI Categories. Each table cell contains the ratio of the 400 code prevalence number to the total number of cell individuals and in parentheses, the equivalent of the ratio in terms of % prevalence.

FRWI (%)	AGE (yrs.)				
	<30	30–39	40–49	> 50	All Ages
<100.0	73/ 5487 (1.3)	102/ 4935 (2.1)	108/ 2086 (5.2)	88/ 809 (10.9)	371/ 13,317 (2.8)
100.0–119.9	47/ 2861 (1.6)	122/ 4009 (3.0)	141/ 1927 (7.3)	101/ 760 (13.3)	411/ 9557 (4.3)
<120.0	120/ 3284 (1.4)	224/ 8944 (2.5)	249/ 4013 (6.2)	189/ 1569 (12.0)	782/ 22,874 (3.4)
≧120.0	12/ 294 (4.1)	20/ 400 (5.0)	22/ 194 (11.3)	9/ 64 (14.1)	63/ 952 (6.6)
All FRWIs	132/ 8642 (1.5)	244/ 9344 (2.6)	271/ 4207 (6.4)	198/ 1633 (02.1)	845/ 23,826 (3.5)

myocardial infarction and sudden death was distinctly and impressively related to the antecedent level of both systolic and diastolic blood pressure. Risk was related not solely to 'hypertension' but was proportional to the level of blood pressure—even at non-hypertensive pressures—from the lowest to the highest recorded." Therefore, if covert CHD is present at all in the ATC population, it appears reasonable to assume that comprehensive cardiological examination would most probably reveal a greater % prevalence of the CHD in the older/obese combined categories with the higher blood pressures than in the younger/thinner combined categories with the lower blood pressures.

A detailed rationale for the relationship between increased resting HR and CHD susceptibility has been presented in a previous report.[18] Although none of the HR values in Table 3 are considered to be medically abnormal,[24] a general pattern of increase with age and obesity is present. The increase in HR with age within each FRWI segment appears to be much smaller than the increase in HR with FRWI within each age segment. In the greater than 50 years column, the HR of the 120.0% or greater FRWI group departs from the trend of increase seen in each of the other segmental age groups. This departure from the general pattern of increase might possibly be ascribed to some measurement artifact or possibly reflect the already accomplished departure from this specific group of overt CHD victims having higher resting HRs. At present, the settlement of this point is moot. However, the general pattern still supports an increasing relative CHD susceptibility with age and obesity and a logical primary focus on the older/obese combined categories for intensified CHD screenings.

Because of the unequivocal documented nature of 400 pathology code incidents, the data in Table 4 constitute the strongest evidence in support of the presence of an increasing relative CHD susceptibility with age and obesity and the concentration of the highest relative susceptibility in the older/obese combined categories. The general patterns of increase in BP and HR with age and obesity parallel the 400 pathology code data. Since the highest % prevalences of the 400 pathology code are concentrated in the older/obese combined categories and since the FHS has shown a definite increased CHD susceptibility and incidence in older and obese males,[2 19] it seems reasonable to hypothesize that the concomitant presence of advanced age, frank obesity (120.0% or greater FRWI) and relatively elevated BP and HR values may reflect a substantial displacement from cardiovascular normality. In any event, it would appear relatively easy to test the hypothesis that more covert CHD exists in the older/obese combined categories with relatively elevated BPs and HRs than in the younger/thinner combined categories with relatively lower BPs and HRs. A test of this hypothesis would consist simply of comprehensive cardiological examination of representative aliquots from these two polar categories at approximately the same point in time.

The detailed rationale for using the age versus FRWI tables of SBP, DBP and HR as an adjunct aid to mass aeromedical screening for detection of covert CHD was presented in the introduction section of this report. Although the combined use of these parameters alone will not detect the presence of covert CHD in a medically unequivocal manner, in complete accord with the FHS findings and the present 400 pathology code data, they are capable of delineating those persons within this population having the highest relative potential for this disease. In the interest of the most efficient, economical manner of detecting covert CHD within the ATC or any other population segment, it appears reasonable to focus comprehensive cardiological examinations initially on those personnel manifesting the highest relative susceptibility to this disease. The paramount virtue of the parametric battery described here as a delineator of relative CHD susceptibility lies in the simplicity of the parametric measurements per se. Resting BP and HR are readily measured with acceptable accuracy. Age, as measured from date of birth, is relatively immune to error. Height and weight, from which the FRWI is calculated, are stated rather than measured data. When stated, both of these parameters are subject to some degrees of error.[20] A detailed report covering height and weight errors in aeromedical certification data is currently in preparation. In the present study, all detected height errors were corrected whereas the stated weights were accepted as the best available data. The directional influences of errors in both of these parameters are such that corrections would strengthen rather than weaken any conclusions reached in this study.

Since resting BP and HR, date of birth, height and weight data are easily obtainable and are, in fact, already included in the standard aeromedical certification examination, no additional expenditure of time or money is involved in their combined use as an adjunct screening aid for the detection of CHD. The earlier mentioned alternative of a comprehensive cardiological examination each year for every ATC personnel is hardly economical or desirable.

The screening identification of any ATC personnel manifesting a high degree of relative CHD susceptibility provides an important starting point for a comprehensive attack on all phases of CHD with the eventual goal of its elimination from this population segment. Initially, the identification of these individuals focuses the most logical site for a sharply defined application of comprehensive cardiological examination. The identification of the highly susceptible individual with or without accompanying covert CHD is especially important in view of the potentially grave aviation effects of sudden and unpredictable incapacitation [16] and in view of the definititive reports that these two types of incapacitation due to CHD are usually preceded by major abnormal displacements of FHS susceptibility parameters[15] and/or covert CHD.[14] It is a policy of the Federal Aviation Administration that controllers who do not successfully pass required physicals are not permitted to man operational positions. The identification of high susceptibility and/or covert CHD individuals would afford the option of pursuing remedial rehabilitation regimens. Individuals possessing real but moderate to minor degrees of susceptibility could optionally engage in remedial programs aimed at partial and/or complete reduction of the susceptibility. Those individuals manifesting normality in all CHD susceptibility indicators could optionally be encouraged through educational channels to engage in preventive maintenance regimens of several varieties. In this latter category, the earliest detection of minor departures from optimum cardiovascular health could be countered swiftly and most efficiently for return to complete cardiovascular normality. A concerted effort of this type at all of these levels could eventually reduce CHD in the ATC population to the barest minimum and hence achieve the fullest meaning for the cardiovascular aspect of the ATC health maintenance program. The degree to which such efforts succeed should be reflected in enhanced aviation safety.

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