Findings that relate physical activity of work to incidence of coronary heart disease have been disputed. This study addresses itself to this problem by examining letter carriers and postal clerks. The findings tend to support the relation between physical activity and heart disease.

THE RELATIONSHIP OF REPORTED CORONARY HEART DISEASE MORTALITY TO PHYSICAL ACTIVITY OF WORK

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THIS STUDY was undertaken in an attempt to confirm or extend the findings reported by Morris, et al.,[1] relating the physical activity of work to coronary heart disease incidence. United States studies in this area include those by Chapman, et al.,[2] and Stamler, et al.,[3] in which no significant relationship was found between physical exertion on the job and coronary disease incidence among Los Angeles civil servants and Chicago utility workers, respectively. Spain and Bradess[4] reported no difference in the average extent of coronary artery occlusion in those with sedentary as compared to active occupations among men coming to autopsy after violent death. Breslow and Buell,[5,6] analyzing occupation reported on death certificates and in census reports for California, found an association favorable to more active occupations, after making an adjustment directed toward standardizing for the socioeconomic differences among activity classes. Zukel, et al.,[7] reported that lack of physical activity was probably related to higher CHD rates in a study of a North Dakota community, and Taylor, et al.,[8] report CHD mortality is inversely related to job activity in a study of railroad clerks, switchmen, and section men.

Except perhaps for Morris' work with bus drivers and bus conductors[1] and his analysis of reported mortality by social class and occupation,[9] the studies relating coronary heart disease mortality to active or sedentary occupations are generally confounded with important differences in socioeconomic status. For this reason the present study deals with a population that minimizes the possible effects of socioeconomic variation on CHD incidence, while at the same time important differences in on-the-job physical activity are included.

This study also examines the relationship in terms of varying lengths of time that the individual had been engaged in active or sedentary work in addition to the more usual comparison of subsequent experience among those who are currently in one group or the other. The study population consists of post office carriers and clerks and, after discussions with appropriate officials* in the agencies concerned, was specifically defined

* The author wishes to gratefully acknowledge the excellent cooperation received from Dr. Glen A. Brough, acting medical director, Post Office Department; Mr. Carlton Beall, postmaster, Washington, D. C.; Mr. M. D. Davis, chief, Reference Service Branch, Federal Records Center, General Services Administration; and Mr. Charles F. Overend, assistant director of operations, Bureau of Retirement and Insurance Civil Service Commission.

to be those persons who received a probational appointment as a carrier or a clerk in the Washington D. C. Post Office at any time between January, 1906, and December, 1940, inclusive and who remained in the D. C. Post Office as a carrier or clerk for five years or more.* Entrance to the study population was cut off in 1940 because it was felt that only a few deaths would occur among those starting work after 1940 and the labors of record search and follow-up would be increased substantially without sufficient information being added to the study to justify them. Thus, unless they died or were lost to observation earlier, all individuals included in this study have had at least 21 years of observation.

The basic elements of the study were first, to identify the population and then through such additional record-searching as would be necessary in the D. C. Post Office, the Federal Records Center in St. Louis where records for inactive employees are kept, or the Bureau of Retirement and Insurance of the Civil Service Commission, to establish job changes and dates relating to post office employment categories, and whether living or dead as of January 1, 1962. The original identification of the study population was possible because the Federal Records Center has on file probational appointment lists for the period specified. Without this "handle" to the study population it would not have been practical to undertake retrospective collection of this kind of prospective data. Miscellaneous follow-up included writing to the individual at his last known address, to other government agencies to which he was reported to have transferred, and employing a professional tracing agency. Whenever the date and place of death was reported, the State Health Department concerned was contacted for a copy of the death certificate.

A total of 2,240 persons have been identified as part of the study population. Follow-up has been fairly successful. The status (living or dead) on January 1, 1962, was determined for over 93 per cent of the cases. The differences between carriers and clerks in the per cent lost to follow-up shown in Table 1 are neither large nor statistically significant.

Based on the collected work histories, the time periods beginning with the original appointment date were classified as employed as a carrier in the D. C. Post Office, a clerk in the D. C. Post Office, or as something else. Each period of employment is identified with the date on which it began and the date on which it ended. It is interesting to note that postal workers, who are generally considered to be stable employees, do a fair

* Calculations on the sample size suitability of the D. C. Post Office were based on information that "not very many" probational appointees dropped out before five years. The proportion actually came to 46 per cent.

Table 1—Follow-up Results

Original Appointment Category	Number in the Study			Per cent Unknown if Alive on January 1, 1962		
	Total*	White	Nonwhite	Total*	White	Nonwhite
Clerk	1,374	1,097	268	6.8	6.7	5.6
Carrier	866	567	296	6.9	8.5	3.4
Total	2,240	1,664	564	6.9	7.3	4.4

* Includes unknown color.

Table 2—Extent of Mixed Service

Original Appointment Category	Number in the Study			Per cent Shifting at Some Time to the Opposite Category		
	Total*	White	Nonwhite	Total*	White	Nonwhite
Clerk	1,374	1,097	268	7.0	8.0	2.6
Carrier	866	567	296	32.8	35.6	27.4
Total	2,240	1,664	564	17.0	17.4	15.6

* Includes unknown color.

amount of transferring from one category to another. Table 2 indicates the approximate extent of these switches and shows that carriers transfer much more frequently to clerk than clerks transfer to carrier. Each person in the study has been coded for the number of years served as a carrier, as a clerk, and as other. If we total the person-years observation as carrier for all persons, 26 per cent of this total is recorded for individuals who also have clerk service. A similar computation on total person-years observation as a clerk shows that 14 per cent of this total is for individuals who also have carrier service.

The carrier and clerk employment categories were strictly construed so as to maintain the general similarity of the two groups. For example, if a carrier transferred from the D. C. Post Office to any other post office outside the Washington D. C. metropolitan area, this employment would be coded as "other," even if he continued as a carrier in his new location. The presumably real differences in state mortality rates pointed out by Sauer and Enterline[10] are thus prevented from affecting direct comparisons of current clerk and carrier employment. Similarly, if a clerk was promoted to foreman or postmaster he was considered to be in the "other" category from that date. Although the new work might be just as sedentary as postal clerk, the new pay scale or social status might affect the risk of CHD to an important degree which would be difficult to standardize for the two groups. Retired or unemployed status are also grouped under category "other." Thus, for each employee, we have dates corresponding to service as a postal clerk in the D. C. metropolitan area, dates corresponding to carrier service in the D. C. metropolitan area, and dates corresponding to all other types of employment activity up to the date of death or the cut-off date of January 1, 1962, unless lost to observation earlier.

Other than data needed for follow-up purposes only, the additional information collected for each person in the study is as follows:

Birth date
Date and classification of original appointment
Color
Height and weight as of original appointment
Date and reported cause of disability retirement
Date, place, and reported cause of death

There were no systematic records of illness (except as reflected in disability retirements) from which to construct morbidity rates and consequently this entire study is focused on differences in reported mortality. The disability retirement information was collected as a precaution against later need but has not yet been utilized in the analysis because of the obvious bias between the two groups: Given almost any condition,

a carrier will have a higher probability of disability retirement as a result of it than will a clerk with the same condition. Of course, if the disability retirement is reflected in later mortality, it is so counted.

Because of the similarity in the carrier-clerk groups in matters of pay, entrance examination, entrance physical, and general social status, it seems reasonable to study differences in reported coronary heart disease mortality rates with full recognition that they will contain diagnostic "errors" for both groups. The strength of the comparison depends on the supposition that one group will not have their death certificates signed chiefly by cardiologists and the other chiefly by GP's and also that no other important bias in reporting of CHD mortality is operating. In view of the difficulty in selecting a primary cause of death when several are reported, this study considers all deaths on which cause 420 (International Statistical Classification of Diseases, Injuries and Causes of Death—Seventh Revision) is reported as CHD deaths. However, because of the fact that diagnosis of coronary heart disease mortality is often difficult, the analysis will uniformly consider both the risk of reported CHD mortality and the risk of mortality from all causes. It would be of interest in any event to know whether any risk change in CHD is reflected in over-all mortality or whether physical activity is merely associated with changing from one cause of death to another.

An item worth considering is whether the groups are different to start with. Perhaps active or relatively sedentary work has little or nothing to do with the subsequent risk of disease and differences relate entirely to original selection. Incidentally, although applicants for clerk and carrier jobs take identical examinations, it is the applicants themselves who select the category for which they wish to be considered. The only initial measurements for which data are routinely available are height, weight, and age. These did not differ between the two groups as shown by Table 3. Certainly this leaves open the question as to whether the groups differ as of original appointment on other characteristics of importance to the study, but as of the present we have no additional evidence either way.

Table 3—Height, Weight, and Age as of Original Appointment

Original Appointment Category	Height (Inches)		Weight (Pounds)		Age (Years)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Total Population*						
Clerk	69.2	2.6	153.5	20.3	27.7	6.9
Carrier	69.1	2.3	153.7	19.5	28.3	6.3
White						
Clerk	69.3	2.4	153.4	20.6	27.4	7.0
Carrier	69.3	2.3	152.9	19.4	28.3	6.6
Nonwhite						
Clerk	69.0	2.5	154.1	19.2	28.9	6.2
Carrier	68.7	2.3	155.3	19.5	28.4	5.5

* Includes unknown color.

The remainder of this paper deals with whites only. Data on nonwhite carriers and clerks will be presented at a later date.

Of crucial importance to the analysis of data of this type is the choice of definition for clerk and carrier. The present study considers seven alternative definitions of "clerk" and "carrier." It will be helpful to examine the data with respect to these in three groupings. Table 4 summarizes the findings with respect to these seven definitions but before considering the results given, it might be useful to describe the way the data being reported here have been summarized.

Subject to the definition selected for study, person-years of observation qualifying under that definition are summarized for the age groupings <35, 35-44, 45-54, and 55-64. Using the corresponding 1950 white male rates for D. C. as a standard, the crude rates for each of the categories Death-All Causes and CHD Deaths in the defined groups are adjusted by the indirect method for the effect of differing person-year age distributions between carrier and clerk groups. The ratio of the indirect age-adjusted rate for clerks to the similarly adjusted rate for carriers is then of the form*

$$\frac{\Sigma P_{2i}R_{si}}{\Sigma P_{1i}R_{si}} \cdot \frac{\Sigma D_{1i}}{\Sigma D_{2i}}$$

where for the i^{th} age group P_1=person-years of clerk observation, P_2=person-years of carrier observation, D_1=deaths among clerks, D_2=deaths among carriers and R_s=standard population rate. If only samples of the observed size in person-years of observation are considered, the sampling variability of this ratio is due solely to the ratio of the total numbers of deaths in the two groups. If we further restrict our sampling model to just those samples with the observed combined total number of deaths, then exact confidence limits for this ratio can be determined from tables of the cumulative binomial distribution.† Multiplying confidence limits for $\frac{\lambda_1}{\lambda_2}$ by the term $\frac{\Sigma P_{2i}R_{si}}{\Sigma P_{1i}R_{si}}$ which is not a

* The following expression, which is the ratio of the indirect age-adjusted rates written out in full, can be simplified by cancelling terms and using D as a substitute symbol for the product of population x rate to arrive at the form given above.

$$\frac{\dfrac{\Sigma P_{si}R_{si}}{\Sigma P_{si}}}{\dfrac{\Sigma P_{1i}R_{si}}{\Sigma P_{1i}}} \cdot \frac{\Sigma P_{1i}R_{1i}}{\Sigma P_{1i}} \Bigg/ \frac{\dfrac{\Sigma P_{si}R_{si}}{\Sigma P_{si}}}{\dfrac{\Sigma P_{2i}R_{si}}{\Sigma P_{2i}}} \cdot \frac{\Sigma P_{2i}R_{2i}}{\Sigma P_{2i}}$$

† A more complete explanation regarding the calculation of confidence limits is as follows:

In this study, the total number of deaths is small relative to the person-years at risk and the number of such deaths can effectively be considered to follow the Poisson distribution. Thus, the sampling variability of the ratio of age-adjusted rates depends on the sampling variability of the ratio of the two Poisson variables—total deaths among clerks and total deaths among carriers. $\left(\frac{\Sigma D_{1i}}{\Sigma D_{2i}}\right)$

The model being considered has no sampling variation in the total number of deaths for clerks and carriers combined. This means that the number of clerk deaths will be distributed like the number of "successes" in a number of binomial trials equal to the total number of deaths. The parameter (θ) for this binomial distribution is the ratio of the Poisson parameter for the distribution of clerk deaths (λ_1) to the sum of the Poisson parameters for clerk and carrier deaths $(\lambda_1+\lambda_2)$. With tables of the binomial distribution we can obtain exact limits on the parameter $\theta=\frac{\lambda_1}{\lambda_1+\lambda_2}$ based on the observed number of clerk deaths and the total number of deaths for clerks and carriers.

However limits on θ also determine limits on $1-\theta$. Using these limits for the ratio

$$\theta/1-\theta = \frac{\lambda_1}{\lambda_1+\lambda_2} \Big/ \frac{\lambda_2}{\lambda_1+\lambda_2} = \frac{\lambda_1}{\lambda_2}$$

we get the exact confidence limits desired, namely those for $\frac{\lambda_1}{\lambda_2}$ the "true" ratio of clerk deaths to carrier deaths.

Table 4—Summary: White Males—Observation to Age 65 (Persons with Less than Five Years Carrier-Clerk Experience Are Excluded Throughout)

Alternative Definitions of "Clerk" and "Carrier"	Person-Years of Observation		Death—All Causes				Reported Death CHD			
	Clerk	Carrier	Number Clerk	Number Carrier	Ratio Clerk/ Carrier Age-Adjusted Rates	Lower 0.95 Confidence Limit for Ratio	Number Clerk	Number Carrier	Ratio Clerk/ Carrier Age-Adjusted Rates	Lower 0.95 Confidence Limit for Ratio
1. Original Appointment Category	30,791	16,205	223	126	1.02	0.85	58	27	1.26	0.84
2. Longer Service Category										
(a) Total observation for those with less than 10 years' service	4,809	2,615	39	33	0.71	0.47	5	4	0.77	0.21
(b) Observation beginning 10th year for those with 10-19 years' service	6,585	2,666	91	50	0.83	0.61	23	13	0.83	0.45
(c) Observation beginning 20th year for those with at least 20 years' service	6,365	3,121	97	39	1.29	0.93	28	12	1.22	0.67
(d) Same as 2(c) but excluding those with mixed service	5,855	2,362	91	30	1.30	0.90	26	8	1.43	0.70
3. Current Service Category										
(a) Without regard to prior classification	22,067	10,773	106	27	1.82	1.26	30	5	2.77	1.21
(b) No prior service in opposite category	19,495	9,485	86	25	1.68	1.14	23	4	2.81	1.10

sampling variable in our model provides the desired confidence limits.

In Table 4 we observe that the mortality ratio for the original appointment classification is 1.02 for all causes and 1.26 for CHD. Neither of these is significantly above 1.00 at the 0.05 level. If there is a difference of larger magnitude than these data reveal it may be diluted by this manner of classification which ignores subsequent shifts in category and mixes up individuals with anywhere from 5 to over 40 years of service.

Categories 2(a) through 2(d) in Table 4 have as a basis of classification, the category in which the individual served the most years, whether it was his starting category or not. Those who served less than 10 years in this longer service group are grouped together in 2(a). Those who served 10-19 years are in 2(b) but the person-years of observation included for this group are limited to the 10th and later years for each individual. By definition, no events could have happened in the first 10 years since everyone had at least 10 years' service. Similarly, the next group 2(c) excludes the first 20 years of observation on each individual included. The last group 2(d) is similar to 2(c) except that any individuals with mixed service (e.g., 24 years as a clerk and 6 years as a carrier) are excluded. This series from 2(a) to 2(d) shows a gradient of increasing risk for clerks relative to carriers; however, none of the values is significantly different from 1.00 at the 0.05 level nor is the slope of the 3 ratios for less than 10, 10 to 19, and 20 and over years of service significantly different from zero. Because they are not unusual sampling deviations from 1.00, no special significance is read into the relatively more favorable experience for clerks as compared to carriers in the under 10- and 10-19-year experience groups. It will however be worth noting whether this "discrepancy" appears in other sets of data analyzed in a similar manner.

The 20-year "pure" grouping has higher ratios than the classification by original appointment for both the All Cause and the CHD mortality categories. The long period of unmixed service preceding the observation under study seems to be sharpening the difference between groups, although this is more noticeable for Death All Causes than for Death-CHD.

The increasing risk for clerks relative to carriers may not have anything to do with the longer period of defined service prior to study observation, but may result from differentials in age-specific rates. As we exclude the first 10 or 20 years from study, we are shifting from use of all age-specific rates to increasing emphasis on just the older ones. These older age groups may show higher relative clerk risk without regard to years of prior service. In this respect, it is helpful to look at Table 5 showing that the single category 55-64 demonstrates about the same pattern as for all ages up to 65.

We now consider the last category of definitions of clerk-carrier service in the study. In all the previous groups, the individuals were classified by some fixed criterion and observation continued until the individual died, was lost from observation, or the study cut-off date was reached. In this category we classify the individual as a carrier for exactly the period he works as a carrier. If he then changes to clerk, this later period of observation is classified (for the appropriate age category) as a clerk. Should he shift back again, more years of observation as a carrier will be added in. In effect, this method of classification simply scores his current status. Each year that he works as a carrier is added to carrier observation in the age group corresponding to his age at that time. Similarly each year worked as a clerk is added to clerk observation. Observation time, when the individual is neither a carrier nor a clerk, is excluded from this series and so are the corresponding

deaths. This category relates current service as a clerk or carrier to deaths while employed as a clerk or carrier.

The first subdivision in this category includes all observation and deaths as defined above. The next subdivision, 3(b), excludes observation time on clerks, and the deaths that might have occurred during it, if any carrier service preceded the clerk employment. Similarly if clerk service precedes carrier employment such carrier observation is excluded.

The mortality ratios for current service, whether restricted to those without prior classification in the opposing category or not, are much higher than any obtained by the previous definitions and are beyond the limits which could reasonably be ascribed to sampling variability (at 0.05 level).

There is a suggestion here that physical activity of 5, 10, or 15 years ago may not be associated with change in current mortality risk. If physical activity such as walking is associated with lower risk, it may be that the walking done "now" or within the last year or two is the important feature and not the activity of long ago. Although it was not statistically significant, we did note an increasing relative risk for clerks as length of service prior to observation was increased. This might seem to be some evidence for the idea that activity long ago is associated with present risk. Perhaps it is, but increasing the period of prior years of service to meet the defined clerk-carrier category also had the effect of reducing the proportion of observation time to age 65 that is not in either clerk or carrier category.

It is also entirely possible that comparison of current service shows such a big differential in risk because there is a selective weeding out of cases. For example, carriers who do not "feel well" might drop out of the carrier group and change to "other" or to clerk in greater proportion than clerks leave their group for the same reason.

We can investigate this by assuming that clerks who have been carriers should have the same death rates as clerks who have always been clerks. Any excess to this assumption will be considered as "chargeable" to the carrier group and "deductible" from the clerk group. Similarly we will assume that those in the "other" category who have been carriers should have the same death rates as those in the other category

Table 5—Age-Specific Rates for White Males Age 55-64 Only

Category at Longer Service		Death All Causes Rate/ 1,000	Death All Causes Ratio Clerk/ Carrier	Death CHD Rate/ 1,000	Death CHD Ratio Clerk/ Carrier
<10 years' service	clerk	16.9	0.32	—	—
	carrier	52.4		7.0	
10-19 years' service	clerk	30.2	0.67	8.0	0.80
	carrier	45.1		10.0	
20+ years' service	clerk	21.8	1.30	6.4	1.15
	carrier	16.7		5.6	
20+ years' pure service	clerk	22.1	1.23	6.1	1.14
	carrier	17.9		5.4	

Table 6—Comparison of Observed and Expected Deaths to Age 65 Among White Males Who Were Carriers but Changed to Clerk or to "Other"

	Total			CHD		
	Observed	Expected	Excess	Observed	Expected	Excess Observed
Change to clerk	20	17.9	2.1	7	5.1	1.9
Change to other	67	56.1	10.9	13	13.6	negative
Total	87	74.0	13.0	20	18.7	1.9

who have been clerks. Again, any excess will be "chargeable" to the carrier group.

These data are summarized in Table 6 which shows that total deaths are 13.0 in excess of reasonable expectation and CHD Deaths 1.9 in excess of reasonable expectation among those who leave carrier service. Certainly there is no strict justification for expecting those who have been carriers to have the same rates as those who have been clerks because we no longer can utilize the general equivalence we have postulated for their clerk-carrier working period. However, it is of interest as an indication whether all or most of the difference observed in current service categories can be associated with a reverse difference in subsequent experience. After adding to the carrier deaths all of the "excess" deaths among clerks and others as computed above and then subtracting from the clerk deaths the "excess" among clerks, the current service mortality ratios are changed from 1.82 to 1.21 for All Cause Deaths and from 2.77 to 1.88 for CHD Deaths.

The revised ratio for CHD Deaths relating current experience of clerks to carriers is still a good bit higher than that for the 20 years or more of unmixed service. The adjustment for excess deaths in later experience has however reduced the All Cause ratio for current experience to below the value measured for the 20-year unmixed service category. Taking as a reasonable estimate, the range between the ratios computed for the 20-year unmixed service category (1.43) and the current service category after adjustment (1.88), this study of postal carriers and clerks seems to show that CHD mortality risk for those in sedentary work is between 1.4 and 1.9 times the risk of those who are more active on the job and that activity of recent years may be more important than the individual's lifetime "average."

The All Cause mortality ratio of about 1¼ for sedentary as compared to active workers suggests the lower CHD mortality rates associated with more active work may be contributing to longevity rather than simply reflecting a shift in cause of death. The relationship of physical activity differences to other causes of death is being studied and will be reported later.

Throughout this study the clerk-carrier differentials have been interpreted as related to the physical activity difference of the two jobs; the key distinction being that between a group required to do a great deal of walking and a group typically engaged in the more sedentary activity of sitting at a desk sorting letters. It is entirely possible that the differences observed are only coincidentally related to physical activity differences and that indoor versus outdoor activity, differential proportions of ciga-

rette smokers, original basis of selection, and so on, are the really meaningful factors.

The clerk/carrier ratio found in this study of about 1.4 to 1.9 times as high a risk for clerks as compared to carriers agrees approximately with what Morris found for early CHD mortality in bus drivers (1.5 age-adjusted) compared to the more active bus conductors (0.8 age-adjusted). The present study suggests in addition that current physical activity may be more closely associated with this differential than is the individual's lifetime "average" for physical activity on the job.

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This paper was presented before the Epidemiology Section of the American Public Health Association at the Ninetieth Annual Meeting in Miami Beach, Fla., October 17, 1962.

Symposium on Odor

The New York Academy of Sciences and the American Society of Heating, Refrigerating and Air Conditioning Engineers are jointly sponsoring an "Odor Symposium" in New York in November, 1963. The objectives of the symposium are to bring together workers in the field and to update knowledge gained since the 1953 symposium on subjects such as odor theory, measurement, and control. Further information from: R. L. Kuehner, Manager, Environmental Control, Roy C. Ingersoll Research Center, Wolf and Algonquin Roads, Des Plaines, Ill.