Long-Term Mortality Experience of Steelworkers

VIII. Mortality Patterns of Open Hearth Steelworkers (A Preliminary Report)

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The need for research into the long-term effects of heat stress has been pointed out in the criteria document prepared by the National Institute for Occupational Safety and Health.[1] This report gives the results of a preliminary investigation of the mortality experience of open hearth steelworkers. Associations between mortality and length of employment in this work area have been examined in order to determine whether extended employment in a hot environment is related to subsequent mortality.

Materials and Methods

Data presented in this report come from a longitudinal study of mortality in the steel industry conducted by the Department of Biostatistics, University of Pittsburgh, with funding from the United States Public Health Service and the American Iron and Steel Institute. The details of the study design and other analyses have been presented in a continuing series of articles in the *Journal of Occupational Medicine*.[2-7] Briefly, the cohort consisted of 58,828 steelworkers employed in 1953 at seven steel plants in Allegheny County, Pennsylvania. Information obtained from plant personnel records included a complete work history from time of initial employment with the firm through 1966, birthdate, race, as well as identifying information useful for follow-up. For men who left employment before January 1, 1967, follow-up was done to determine vital status. Only 54 individuals (less than 0.1%) were lost to follow-up.

For all decedents, copies of death certificates were obtained from appropriate state offices of vital statistics. A nosologist trained at the National Vital Statistics Division of the United States Public Health Service coded the underlying cause of death from the death certificates according to the Seventh Revision of the International List.[8]

In analyzing the data, each worker ever at the open hearth prior to the end of 1953 has been classified according to race, age at entry to the study, calendar years of observation (1953-1957, 1958-1962, 1963-1966), and length of employment in the open hearth. All men never in the open hearth through 1966 have been utilized as the control group.

The expected number of deaths from each cause was calculated for each of the subgroups specified above under the assumption that both open hearth workers and controls have the same death rate within each subgroup. The total expected number of deaths is the sum of the specific rates for the total workers in the subgroups multiplied by the number of open hearth workers at risk in the subclass. The relative risk is a weighted average of the observed and expected number of deaths for each subgroup, where the weights are approximately proportional to the precision within each subclass. To test whether the relative risks differ significantly from one, a summary chi-square with one degree of freedom has been calculated.[9,10]

The Open Hearth

The basic process of open hearth steelmaking, although slowly being phased out in the United States, still exists as a primary method in some areas. In general each furnace requires a three man crew supervised by a foreman who is responsible for a number of furnaces and crews. The liquid or gas utilized by the furnace as a fuel melts pig iron, scrap steel, limestone and other elements (if required for alloy) to form the actual steel. Men working in close proximity to the open hearth furnace are exposed at times to intense heat stress while performing relatively strenuous physical work. The effects of this exposure on heart rate and body temperature have been studied in great detail by Minard *et al.*[11] However, the long-term effects of heat stress have not been previously evaluated.

Findings and Discussion

Table 1 presents the observed and expected mortality and relative risks for all causes. For the 9,655 white open hearth workers and the 2,335 nonwhite open hearth workers the overall mortality is similar to that of other steelworkers, with the relative risks being slightly less than one. When length of exposure at the open hearth is considered, a similar result is observed.

Because of the physiological effect of heat on the heart and circulatory system, the mortality from cardiovascular-renal diseases (CVR) among workers in a hot environment is of particular interest. Table 2 summarizes our findings for workers with various lengths of employment at the open hearth. Results for both white and nonwhite workers are consistent with a deficit in mortality from this cause. The relative risks are 0.90 ($P < .01$) and 0.89 (non-sig.) for white and nonwhite open hearth workers, respectively. The risks by length of time employed are consistently less than 1.0, with the exception of nonwhite open hearth workers with over 22 years of employment, where the relative risk is 1.07 (non-sig.).

In order to investigate this observation in more detail, the data have been further subdivided into more specific cardiovascular disease groups. Since, in general, relative risks for the white workers were similar to those for the nonwhite workers, only the combined age-race-adjusted relative risks will be shown in the following tables. Results will be shown separately by race whenever any appreciable difference is noted in the mortality risks.

As one can see in Table 3, the more favorable mortality experience is present for arteriosclerotic heart disease,

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Table 1. — Populations (N), Observed (Obs.), and Expected (Exp.) Numbers of Deaths, and Disease-Specific Relative Mortality Risks for All Open Hearth Workers by Race and Cumulative Years of Exposure. Allegheny County Steelworkers, 1953-1966.

All Causes

Cumulative Years of Exposure	White				Nonwhite			
	N	Obs.	Exp.	Rel. Risk[1]	N	Obs.	Exp.	Rel. Risk[1]
< 2	4132	477	480.0	0.99	684	100	93.2	1.09
2 -	2092	240	247.0	0.97	654	83	81.5	1.02
7 -	1108	155	153.5	1.01	564	101	107.0	0.93
12 -	850	151	159.8	0.94	132	29	33.5	0.84
17 -	345	62	72.1	0.84	54	16	13.8	1.19
> 22	1128	350	358.6	0.97	247	80	92.8	0.82
Total	9655	1435	1471.9	0.97	2335	409	421.8	0.96

[1]Significance of Relative Risk (Rel. Risk) based on Summary Chi-Square with one degree of freedom.

Table 2. — Populations (N), Observed (Obs.), and Expected (Exp.) Numbers of Deaths, and Disease-Specific Relative Mortality Risks for All Open Hearth Workers by Race and Cumulative Years of Exposure. Allegheny County Steelworkers, 1953-1966. Cardiovascular-Renal Diseases (ICD 330-334, 400-468, 592-594)

Cumulative Years of Exposure	White				Non-white			
	N	Obs.	Exp.	Rel. Risk[1]	N	Obs.	Exp.	Rel. Risk[1]
< 2	4132	237	259.2	0.90	684	40	40.4	0.99
2 -	2092	118	133.9	0.87	654	26	35.6	0.69
7 -	1108	82	85.5	0.95	564	44	49.7	0.87
12 -	850	89	90.9	0.98	132	15	16.4	0.90
17 -	345	40	41.3	0.97	54	4	6.6	0.59
> 22	1128	182	206.6	0.86	247	49	46.6	1.07
Total	9655	748	817.3	0.90 †	2335	178	195.4	0.89

[1]Significance of Relative Risk (Rel. Risk) based on Summary Chi-Square with one degree of freedom.
†Significant at 1% level.

Table 3. Populations (N), Observed (Obs.), and Expected (Exp.) Numbers of Deaths, and Disease-Specific Relative Mortality Risks for All Open Hearth Workers by Cumulative Years of Exposure. Allegheny County Steelworkers, 1953-1966.

Cumulative Years of Exposure	Arteriosclerotic Heart Disease, Including Coronary Disease (ICD 420)				Hypertensive Heart Disease (ICD 440-447)			Vascular Lesions Affecting Central Nervous System (ICD 330-334)		
	N	Obs.	Exp.	Rel. Risk[1]	Obs.	Exp.	Rel. Risk[1]	Obs.	Exp.	Rel. Risk[1]
< 2	4816	187	200.1	0.93	18	18.3	0.98	38	44.7	0.84
2 -	2746	98	110.1	0.88	6	11.3	0.51	20	26.0	0.76
7 -	1672	84	82.9	1.02	10	11.1	0.89	18	22.9	0.77
12 -	982	78	71.3	1.10	3	6.7	0.44	13	16.6	0.78
17 -	399	31	31.9	0.97	1	2.9	0.34	7	7.4	0.94
> 22	1375	137	163.0	0.82 *	17	16.9	1.01	45	43.8	1.03
Total	11990	615	659.3	0.93	55	67.2	0.81	141	161.4	0.86

[1] Significance of Relative Risk (Rel. Risk) based on Summary Chi-Square with one degree of freedom.
* Significant at 5% level.

although the overall relative risk (0.93) is somewhat greater than for the total CVR category. For workers with 12 to 17 years exposure, the relative risk is 1.10, but this does not represent any significant excess over the mortality from this disease among other steelworkers. Hypertensive heart disease, Table 3, also shows a deficit in mortality among open hearth workers, and a similar result is seen for vascular lesions of the central nervous system. Although measurement data on heat stress were not available to us, we were able to subdivide the workers into heat stress groups by using the steel industry job descriptions, referring to the exposures mentioned under surroundings. We recognize that this has limitations, but believe that it probably is fairly reliable in identifying the jobs with intense heat exposure. A worker was assigned to that heat category (see Table 6) in which he worked for the longest period of time. The category of jobs which do not mention heat includes laborers who may actually have had such exposure.

Table 4 compares the observed and expected mortality from cardiovascular-renal diseases for the workers by heat stress group. It is interesting that the lowest relative risk (0.70) occurs for workers with the intense heat stress over considerable time. However, the next higher relative risk of 0.88 ($P < .01$) is the group where heat stress is not mentioned. Interpretation of this finding is difficult without more precise information on exposure to heat stress. Although we have not considered the amount of physical exertion required by the jobs, it may play a role in the deficit pattern of cardiovascular mortality seen among open hearth workers. The effects of selection in original work assignments and with respect to continued employment in the open hearth area may also be important factors.

Examination of mortality from other causes, particularly respiratory diseases, is worthwhile because of the possibility of exposure to iron oxide and other chemicals in the work environment. Table 5 gives the mortality from lung cancer by length of open hearth experience. Relative risks tend to be less than one, although all are within the range expected by random variation. Observed mortality from non-malignant

Table 4. — Populations (N), Observed (Obs.), and Expected (Exp.) Numbers of Deaths and Disease-Specific Relative Mortality Risks from Cardiovascular-Renal Diseases (ICD 330-334, 400-468, 592-594) for All Open Hearth Workers by Type of Heat Exposure. Allegheny County Steelworkers, 1953-1966.

Type of Heat Exposure	N	Obs.	Exp.	Rel. Risk[1]
All Workers	11990	926	1012.7	0.90†
Extended Periods of Intense Heat Exposure	195	15	21.0	0.70
Intervals of Intense Heat Exposure	1453	159	160.2	0.99
Other Heat Exposure	667	68	71.0	0.95
Heat Not Mentioned	9675	684	763.0	0.88†

[1]Significance of Relative Risk (Rel. Risk) based on Summary Chi-Square with one degree of freedom.
†Significant at 1% level.

Table 5. — Populations (N), Observed (Obs.) and Expected (Exp.) Numbers of Deaths, and Disease-Specific Relative Mortality Risks for All Open Hearth Workers by Race and Cumulative Years of Exposure. Allegheny County Steelworkers, 1953-1966. Lung Cancer (ICD 162-163)

	White				Non-White			
Cumulative Years of Exposure	N	Obs.	Exp.	Rel. Risk[1]	N	Obs.	Exp.	Rel. Risk[1]
< 2	4132	26	30.0	0.86	684	5	7.0	0.69
2 -	2092	21	15.9	1.35	654	1	5.9	0.16
7 -	1108	8	9.5	0.84	564	10	9.3	1.09
12 -	850	9	10.5	0.85	132	1	2.7	—
17 -	345	3	4.8	—	54	3	1.2	—
> 22	1128	20	22.3	0.89	247	5	6.8	0.71
Total	9655	87	93.1	0.93	2335	25	32.8	0.74

[1]Significance of Relative Risk (Rel. Risk) based on Summary Chi-Square with one degree of freedom.
— Less than Five Deaths.

Table 6. Populations (N), Observed (Obs.), and Expected (Exp.) Numbers of Deaths, and Disease-Specific Relative Mortality Risks for All Open Hearth Workers by Race and Cumulative Years of Exposure Allegheny County Steelworkers, 1953-1966. Non-Malignant Respiratory Diseases (ICD 470-527)

	White				Non-White			
Cumulative Years of Exposure	N	Obs.	Exp.	Rel. Risk[1]	N	Obs.	Exp.	Rel. Risk[1]
< 2	4132	17	16.3	1.05	684	6	5.0	1.23
2 -	2092	10	8.4	1.20	654	8	4.5	1.96
7 -	1108	6	5.2	1.16	564	2	5.4	0.34
12 -	850	6	5.6	1.08	132	2	1.8	—
17 -	345	0	2.5	—	54	1	0.7	—
> 22	1128	13	14.0	0.92	247	2	5.1	0.36
Total	9655	52	51.9	1.00	2335	21	22.5	0.92

[1] Significance of Relative Risk (Rel. Risk) based on Summary Chi-Square with one degree of freedom.
— Less Than Five Deaths.

Table 7. — Populations (N), Observed (Obs.) and Expected (Exp.) Number of Deaths, and Disease-Specific Relative Mortality Risks for All Open Hearth Workers by Cumulative Years of Exposure. Allegheny County Steelworkers, 1953-1966.

Cumulative Years of Exposure	N	Diseases of the Digestive System (ICD 530-587) Obs.	Exp.	Rel. Risk[1]	Diseases of Stomach and Duodenum (ICD 540-545) Obs.	Exp.	Rel. Risk[1]
< 2	4816	41	31.4	1.35	10	5.4	2.02
2 -	2746	18	17.5	1.03	4	2.8	—
7 -	1672	16	12.7	1.29	5	2.3	2.42
12 -	982	15	9.9	1.55	4	1.8	—
17 -	399	4	4.3	0.92	0	0.8	—
+ 22	1375	22	20.5	1.08	8	4.5	1.92
Total	11990	116	96.3	1.22 *	31	17.6	1.87 †

[1] Significance of Relative Risk (Rel. Risk) based on Summary Chi-Square with one degree of freedom.
* Significant at 5% level.
† Significant at 1% level.
— Less Than Five Deaths.

Table 8. — Populations (N), Observed (Obs.), and Expected (Exp.) Numbers of Deaths, and Disease-Specific Relative Mortality Risks from Diseases of Stomach and Duodenum (ICD 540-545) for All Open Hearth Workers by Type of Heat Exposure. Allegheny County Steelworkers, 1953-1966.

Type of Heat Exposure	N	Obs.	Exp.	Rel. Risk[1]
All Workers	11990	31	17.6	1.87 †
Extended Periods Of Intense Heat Exposure	195	0	0.8	—
Intervals of Intense Heat Exposure	1453	7	2.8	2.55 *
Other Heat Exposure	667	2	1.2	1.64
Heat Not Mentioned	9675	22	12.8	1.80

[1] Significance of Relative Risk (Rel. Risk) based on Summary Chi-Square with one degree of freedom.
* Significant at 5% level.
† Significant at 1% level.
— Less Than Five Deaths.

respiratory diseases is also similar to that of other steelworkers (Table 6).

The only cause of death for which a significant excess was noted was for the category of diseases of the digestive system (Table 7). Mortality from these causes was 22% greater than expected ($P < .05$). Closer inspection of the more detailed information revealed that the excess was confined primarily to the diseases of the stomach and duodenum, mostly ulcers. The excess is present for most exposure-years groups and is consistent for both races. When the workers are subdivided into heat exposed groups as defined earlier (Table 8), no clear pattern or relationship emerges, although the highest relative risk is observed among men exposed to intense heat at intervals.

Summary

The findings in this report of a deficit in mortality from cardiovascular diseases and an excess in diseases of the digestive system among open hearth workers indicate the need for further study of men working in hot environments. In future reports we hope to refine the comparisons by obtaining data which will enable classification of workers more precisely by intensity and duration of exposure within the open hearth. Of particular importance in future work are the evaluation of possible relationships between the actual levels of heat exposure and subsequent morbidity and mortality, as well as possible interactions between heat stress and physical exertion in terms of the incidence of heart disease and other select diseases.

References

1. Criteria for a Recommended Standard . . . Occupational Exposure to Hot Environments. U.S. Department of Health, Education, and Welfare. National Institute for Occupational Safety and Health, 1972 (HSM 72-10269).

2. Lloyd JW and Ciocco A: Long-Term Mortality Study of Steelworkers: I. Methodology. *J Occup Med* **11**:299-310, 1969.

3. Robinson H: Long-Term Mortality Study of Steelworkers: II. Mortality by Level of Income in Whites and Nonwhites. *J Occup Med* **11**:411-416, August 1969.

4. Redmond CK, Smith EM, Lloyd JW, and Rush HW: Long-Term Mortality Study of Steel workers: III. Follow-up. *J Occup Med* **11**:513-521, 1969.

5. Lloyd JW, Lundin FE Jr, Redmond CK, et al.: Long-Term Mortality Study of Steelworkers: IV. Mortality by Work Area. *J Occup Med* **12**:151-157, 1970.

6. Lloyd JW: Long-Term Mortality Study of Steelworkers: V. Respiratory Cancer in Coke Plant Workers. *J Occup Med* **13**: 53-68, 1971.

7. Redmond CK, Ciocco A, Lloyd JW, et al.: Long-Term Mortality Study of Steelworkers: VI. Mortality from Malignant Neoplasms Among Coke Plant Workers. *J Occup Med* **14**:621-629, 1972.

8. Manual of the International Statistical Classification of Disease, Injuries and Cause of Death. WHO, Geneva, Switzerland. Seventh Revision, 1957.

9. Mantel N, Haenszel W: Statistical Aspects of the Analysis of Data from Retrospective Studies of Disease. *J Nat Cancer Inst* **32**: 719-748, 1959.

10. Mantel N: Evaluation of Survival Data and Two New Rank Order Statistics Arising in its Consideration. *Cancer Chemother Rep* **50**: 163-170, 1966.

11. Minard D, Goldsmith R, Farrier PH Jr., and Lambiotte BJ Jr: Physiological Evaluation of Industrial Heat Stress. *JAIHA* **32**:17-28, 1971.

This research supported in part by Contract No. HSM 099-71-32. The authors wish to acknowledge Miss Mary Preininger who wrote the computer programs and Mrs. Marian Heid for coding the death certificates.