**Sex differences in mortality factors in the Los Alamos National Lab**

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**INTRODUCTION**

As an outgrowth of the U.S. government’s immense investment during World War II, a series of nuclear weapon designing, constructing, and testing sites were confidentially set up nationwide. Los Alamos National Laboratory (LANL), one of the retaining sites located in the mountains of northern New Mexico, has undertaken nuclear physics and weapons design until now [1]. These existing studies pose LANL workers at a risk of radiation exposure, including external x-rays, gamma-rays and neutrons and intakes of tritium and plutonium isotopes [2].

With growing interest in assessing health effects of low-dose radiation exposure, epidemiological studies were conducted focusing on early nuclear industry workers. In general, increased body burdens and cause-specific diseases associated with various radioisotopes and materials intake were well documented by occupational health practitioners in the field of radiation protection [3]. Epidemiological analysis of cohorts who were employed at LANL before 1978 revealed elevated risks of esophagus cancer, bone cancer, and central nervous system cancer among both female and male workers. [1, 2 ,4].

However, the studies to date tend to evaluate the relationship between radiation exposure and health effects among males and females separately. Little is known about if low-dose radiation exposure has disproportionately affected the health outcomes regarding gender. The following study, therefore, aims to draw out conclusions regarding gender by comparing health outcomes (primarily mortality and radiation-related body burden) among radiation-exposed workers when compared with their unexposed coworkers. Our primary hypothesis of this study is that gender may serve as a potential effect modifier in the relationship between radiation exposure and adverse health outcomes.

**METHODS & MATERIALS**

*Data*

The Los Alamos National Laboratory (LANL) collected data on 6,790 women who were employed at LANL between 1943 and 1978 in a cohort mortality study. Similarly, LANL collected data on 15727 males between 1943 and 1977 who were employed at LANL. More details on the data collection process have been published elsewhere [1].

*Analytical Subpopulation*

The LANL collected data on 6,790 female and 15,727 male employees for two independent studies. We combined both data sets, resulting in 22,517 eligible participants. For the current study, we excluded 18,661 participants who did not report a death date, as we were interested in participants who had a recorded death. The analytical subpopulation was n=3,856.

For a secondary analysis, we focused on individuals who were monitored for plutonium exposure. We excluded 18,077 individuals who were not monitored for plutonium and also excluded 3,814 participants who did not report a death date. The analytical subpopulation for the secondary analysis was n=626.

*Outcomes*

We examined the following series of outcome variables. First, we examined age at reported death. This variable was constructed by subtracting the reported death date from the reported birth date. Second, we examined the body burden in nCi and nCi-years, independently. Body burden refers to the total amount of these chemicals that are present in the human body as of 12/31/1984.

*Statistical analysis*

First, we generated descriptive statistics to characterize the study sample by sex (Table 1). Second we used t-tests to examine differences in age at death, body burden in nCi, and body burden in nCi-years between males and females. We report the means, standard deviations, t-statistics assuming unequal variances, and corresponding p-values in Table 2. We repeated t test analysis using the subpopulation only containing participants who were monitored for plutonium. Results are reported in Supplemental Tables 1.

**RESULTS**

The average age of death was 58.3 years for females and 63.2 years for males. For females, 43.7% reported high school education, whereas only 28.4% of males reported high school education. However, 30.9% of males reported only grade school education whereas only 17.1% of females reported grade school education. A majority of males were white (96.5%) and all females were white.

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| --- | --- | --- | --- |
| **Table 1.** Demographics of the LANL sample. | | | |
|  |  |  |  |
|  |  | **Female  n=536** | **Male  n=3,320** |
|  |  | **Mean (SD)** | |
| **Age at death** | | 58.32 (13.05) | 63.22 (14.14) |
|  |  | **%** | |
| **Education** | |  |  |
|  | Grade school | 17.16 | 30.87 |
|  | Some high school | 13.62 | 10.69 |
|  | High school graduate | 43.66 | 28.43 |
|  | Associates degree | 3.73 | 0.99 |
|  | College graduate | 17.16 | 12.11 |
|  | Advanced degree | 3.92 | 12.44 |
|  | Unknown | 0.75 | 4.46 |
| **Race** | |  |  |
|  | Black | 0 | 0.21 |
|  | Other | 0 | 1.08 |
|  | Unknown | 0 | 2.17 |
|  | White | 100 | 96.54 |

From our t-tests with an unequal variance assumption, we found that the age at death was significantly different between females and males (t=-7.96, p<0.001) with males having a higher average age at death (Figure 1). Radioactive body burdens of female workers were lower than that of males and also had a statistically significant difference (t=-4.07, p<0.001). Lastly, the cumulative radioactive body burdens of female workers was also lower than that of males (t=-4.53, p<0.001)

**Table 2.** T-test results for main analytical sample.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Mean (SD) for females** | **Mean (SD) for males** | **t statistics** | **p-value** |
| Age at death | 58.32 (13.05) | 63.22 (14.14) | -7.96 | p<0.001 |
| Body burden in nCi | 1.64 (21.08) | 6.85 (51.69) | -4.07 | p<0.001 |
| Body burden in nCi-years | 0.05 (0.56) | 0.29 (2.71) | -4.53 | p<0.001 |

**Figure 1.** Distribution of age at death.

Chart, histogram

Description automatically generated

For our secondary analysis using only individuals who were monitored for plutonium exposure, we only found a significant difference in the radioactive body burdens between females and males (t=-2.03, p=0.046)

**Supplemental Table 1.** T-test results for secondary analytical sample.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Mean (SD) for females** | **Mean (SD) for males** | **t statistics** | **p-value** |
| **Age at death** | 57.86 (11.40) | 61.77 (13.76) | -1.95 | 0.059 |
| Body burden in nCi | 25.16 (79.88) | 38.46 (117.5) | -0.93 | 0.358 |
| Body burden in nCi-years | 0.71 (2.11) | 1.61 (6.27) | -2.03 | 0.046 |

**DISCUSSION**

The results of the analyses in the study of 3856 eligible workers at the LANL indicated a higher age at death in males than females, whereas a lower radioactive body burden, and lower cumulative radioactive body burden of female than male workers. However, in our secondary analyses, no significant differences were found in the age at death and the cumulative radioactive body burden among male and female workers, although a higher radioactive body burden was shown in males over females. Generally, males were shown to receive more radiation exposure than females, but males still have a longer lifespan than females.

The finding of longer lifespan in males are consistent with previous epidemiology studies, especially those under workplace settings, which validated that gender extensively served as a key effect modifier. In this case, males were claimed to have superior health outcomes regarding its linkage to the social, economic and biological determinants and consequences of diseases and conditions [5,6]. A possible assumption for the higher radioactive body burden in male workers can be the existence of gender stereotypes in the workplace 50 years ago. The different subdivided types of work among male and female workers may cause workers of the two genders disproportionately exposed to environmental radiation exposure, despite their comparable working hours. Also, lack of records in detailed types of work in the data set increases the credibility of this hypothesis. In addition, Nguyen et al.[7] suggested in their study that females were more likely to have better knowledge and overall awareness of self-protection, which confirms the idea that females may protect themselves better from radiation hazards compared with males.

Several limitations of the current study need to be acknowledged. First, among all 22,517 workers employed between 1943 and 1980, 18,661 participants were excluded for lack of death date records. The decrease in sample size can reduce the power of the study and increase the margin of error. Second, health hazards caused by low-dose radiation theoretically require longer time to appear, leading to the insufficiency of data used for current analysis. Third, lacking information of working types of workers in LANL may introduce potential selection bias into the exposure assessment step.

Future research should be therefore concentrated on including up-to-date mortality data and types of work information into analysis. Also, contrastive evaluation analysis of workers in similar nuclear laboratories such as Hanford, Savannah River and Rocky Flats will be needed [1].

**CONCLUSIONS**

Of all workers in LANL between 1943 and 1977, females tended to die earlier compared with males. However, males tended to have more radioactive body burden in both instant and cumulative measurement. Of workers who were monitored for plutonium exposure during that time, there is no significant difference in both death ages and radioactive body burden between females and males.

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