Analysis of Mortality in the HTDS Cohort

An analysis was conducted to investigate whether the mortality experience in the HTDS cohort overall was unusually high, relative to what would be expected based on the mortality experience of the population of the same region over the same time period. Additional analyses were conducted to determine whether there was any indication of an excess in mortality in the HTDS cohort from conditions that might be related to one or more of the primary outcomes of interest.

In this study, 527 (10.1%) of the 5199 individuals originally identified were confirmed as deceased and an additional 16 (0.3%) were located alive but died before participating in the HTDS. A death certificate was obtained for 504 (93% of the 543) in order to determine the cause of death for each person. In the remaining 39, cause of death was ascertained from the source of information which confirmed the death (usually a close relative).

Included in the mortality analyses were all living located subjects, as well as all deceased subjects for whom both age and cause of death could be ascertained. Causes of deaths for cohort members were crosstabulated by age at death. Standardized mortality ratios (SMRs) were calculated for each cause of death to assess whether the morality experience of the selected cohort differed from what would be expected based on the mortality experience of the population of the State of Washington over the same period of follow-up. The calculation of SMRs and their confidence interval are described in Breslow and Day (110). The person-years for the Hanford cohort were calculated based on a program developed by Wood, Richardson, and Wing (111). Inexact death dates in the Hanford cohort were assigned values at the midpoint of the range, i.e., if the month and year was known but not the day, it was assigned as 15; if only the year was known the month and day were assigned as July 1, etc.

The death rates for the population of Washington State (i.e., the rates to which the mortality experience of the selected cohort was compared) were obtained from historical mortality data and other data published by or otherwise available from the National Center for Health Statistics, the State of Washington, and the U.S. Bureau of the Census. For the years 1940-1965 the mortality data were based on tables from Vital Statistics of the United States. The 1941 data were applied to 1940, since no appropriate data from 1940 could be found. For the years 1970-1980 and 1990, the source of the mortality data was Washington State death files previously obtained by the HTDS to perform matches to the study cohort. These files only had the year of death and not the month and day, and thus date of death was assigned as July 1. For 1985 and 1995, the source of the mortality data was Washington State death files from a CDROM produced by the State of Washington. Population estimates for the State of Washington were based on the U.S. Census, using interpolation for the years between censuses.

Tables xx and xx show the distribution of deaths in the HTDS cohort according to eleven categories of cause of death for females and males, respectively. There were 199 deaths in females and 344 deaths in males, with no known age of death for two of the males. For both sexes, the largest proportion of deaths occurred under one year of age (36% for both males and females). Most of these deaths were due to conditions in the perinatal period or congenital anomalies. Approximately 31% of the deaths in females were due to these two causes, as were approximately 27% of the deaths in males.

Table Appendix 23-1. Cause of Death by Age at Death for Females

	Age at Death (years)									
Cause of Death	<1	1-4	5-9	10-14	15-19	20-29	30-39	40-49	50-59	Total
Infectious/parasitic	2	3	0	0	0	0	0	0	0	5
Malignant Neoplasms	0	1	1	1	1	1	6	20	11	42
Diabetes	1	0	0	0	0	0	0	1	2	4
Cardiovascular Disease	0	0	0	0	1	0	2	11	2	16
Pneumonia & influenza	3	1	0	0	0	0	1	0	0	5
Gastrointestinal disorders	0	0	0	0	0	0	0	0	0	0
Congenital Anomalies	13	1	1	0	0	1	0	0	0	16
Conditions in the perinatal period	45	0	0	0	0	0	0	0	0	45
External causes of injury/poisoning	1	9	3	3	3	4	9	4	3	39
All other causes	7	5	3	0	2	2	2	3	3	27
Total	72	20	8	4	7	8	20	39	21	199

Table Appendix 23-2. Cause of Death by Age at Death for Males

	Age at Death (years)									
Cause of Death	<1	1-4	5-9	10-14	15-19	20-29	30-39	40-49	50-59	Total
Infectious/parasitic	9	2	1	1	0	0	0	6	1	20
Malignant Neoplasms	0	1	1	0	3	4	3	14	3	29
Diabetes	1	1	0	0	0	0	1	1	0	4
Cardiovascular Disease	0	0	0	0	1	1	5	22	10	39
Pneumonia & influenza	13	1	0	0	0	0	0	0	0	14
Gastrointestinal disorders	1	0	0	0	0	0	1	6	0	8
Congenital anomalies	21	1	1	0	0	2	0	1	0	26
Conditions in the perinatal period	65	0	0	0	0	0	0	0	0	65
External causes of injury/poisoning	5	7	3	3	7	34	24	19	4	106
All other causes	8	3	0	1	2	3	4	4	6	31
Total	123	16	6	5	13	44	38	73	24	342

Note: 2 males, for whom the date of death is unknown, died of other causes and are omitted from this table.

Table xx shows standardized mortality ratios for the ten cause of death categories by sex. Overall, there was no increase in total mortality over what would be expected based on the mortality experience of the population of Washington State during the same time period (SMR = 0.97; 95% Confidence Interval (CI) = 0.89, 1.06). This was true for both females (SMR = 0.96) and males (SMR = 0.98). However, there was an excess in deaths due to conditions of the perinatal period (SMR = 1.69, 95% CI = 1.39, 2.04), which was found in both females (SMR = 1.70) and males (SMR = 1.68).

Table Appendix 23-3. Standardized Mortality Ratio (SMR), by Cause of Death and Sex

	Female		Male		Total	
Cause of Death	SMR	95% CI	SMR	95% CI	SMR	95% CI
Infectious/parasitic	0.25	0.08, 0.59	0.51	0.31, 0.79	0.42	0.27, 0.63
Malignant neoplasms	1.16	0.84, 1.57	0.84	0.56, 1.20	1.00	0.78, 1.26
Diabetes	1.05	0.29, 2.69	0.76	0.21, 1.94	0.88	0.38, 1.73
Cardiovascular disease	1.20	0.68, 1.94	1.27	0.90, 1.73	1.24	0.94, 1.62
Pneumonia & influenza	0.38	0.12, 0.88	0.80	0.44, 1.34	0.62	0.37, 0.96
Gastrointestinal disorders.	0	--	1.09	0.47, 2.15	0.67	0.29, 1.31
Congenital anomalies	1.11	0.64, 1.81	1.26	0.82, 1.85	1.20	0.86, 1.62
Conditions of perinatal period	1.70	1.24, 2.27	1.68	1.30, 2.14	1.69	1.39, 2.04
External causes of injury/poisoning	1.20	0.85, 1.64	1.12	0.92, 1.36	1.14	0.96, 1.35
All other causes	0.66	0.43, 0.96	0.50	0.34, 0.71	0.56	0.43, 0.73
Total	0.96	0.84, 1.11	0.98	0.88, 1.09	0.97	0.89, 1.06

Analyses were conducted to investigate whether there was any excess in mortality according to geostratum of birth. Table xx shows standardized mortality ratios according to geostratum, by sex. The only excess in mortality was observed among persons from the geostrata defined by birth in Franklin County (SMR = 1.61, 95% CI = 1.15, 2.20). This excess mortality in Franklin County was found for males (SMR = 1.66, 95% CI = 1.09, 2.44), but was only suggestive for females (SMR = 1.53, 95% CI = 0.83, 2.56).

Table Appendix 23-4. Standardized Mortality Ratio (SMR) for All Causes of Death, by Geostratum and Sex

	Female		Male		Total	
Geostratum	SMR	95% CI	SMR	95% CI	SMR	95% CI
Richland	0.81	0.46, 1.31	0.69	0.44, 1.04	0.74	0.52, 1.01
Pasco/Kennewick	1.10	0.85, 1.40	1.02	0.84, 1.23	1.05	0.90, 1.22
Walla Walla (city)	1.01	0.58, 1.65	0.79	0.49, 1.20	0.87	0.61, 1.20
Benton County	1.09	0.80, 1.44	1.13	0.90, 1.40	1.11	0.93, 1.32
Franklin County	1.53	0.83, 2.56	1.66	1.09, 2.44	1.61	1.15, 2.20
Walla Walla County	0.43	0.18, 0.84	0.73	0.46, 1.10	0.62	0.42, 0.88
Okanogan County	0.85	0.34, 1.75	0.98	0.52, 1.67	0.93	0.57, 1.43
Ferry/Stevens Counties	0.95	0.41, 1.86	0.96	0.51, 1.63	0.95	0.59, 1.46
Adams County	0.69	0.38, 1.16	0.86	0.58, 1.23	0.80	0.58, 1.07
Total	0.96	0.84, 1.11	0.98	0.88, 1.09	0.97	0.89, 1.06

In an attempt to see whether the observed excesses in mortality were concentrated among persons born around the time of the peak releases from Hanford (i.e., 1945 and 1946), a number of analyses were

repeated separately for the birth cohorts defined by the period 1940-44, and 1945-46. Table xx shows essentially no difference in mortality between the 1945-46 birth cohorts and the 1940-1944 birth cohorts.

Table Appendix 23-5. Standardized Mortality Ratio (SMR) for All Causes of Death, by Birth Year Category and Sex

	Female		Male		Total	
Birth Year	SMR	95% CI	SMR	95% CI	SMR	95% CI
1940-1944	1.00	0.85, 1.17	0.95	0.83, 1.08	0.97	0.88, 1.07
1945-1946	0.86	0.63, 1.16	1.06	0.86, 1.29	0.99	0.83, 1.16

When considering mortality by birth year within geostrata, there was no evidence that the later birth cohorts experienced a greater excess in mortality in those counties with little or no excess mortality overall (Table xx). In Franklin County the excess mortality relative to expected was a little higher for the 1945-46 birth cohort than the 1940-1944 birth cohort, but this difference was not statistically significant.

Table Appendix 23-6. Standardized Mortality Ratio (SMR) for All Causes of Death, by Geostratum and Birth Year Category

	1940-1944		1945-1946	
Geostratum	SMR	95% CI	SMR	95% CI
Richland	0.69	0.37, 1.18	0.76	0.50, 1.12
Pasco/Kennewick	1.01	0.85, 1.19	1.22	0.86, 1.67
Walla Walla (city)	1.00	0.66, 1.46	0.64	0.31, 1.18
Benton County	1.05	0.86, 1.27	1.45	0.96, 2.11
Franklin County	1.53	1.03, 2.18	1.95	0.94, 3.58
Walla Walla County	0.56	0.33, 0.88	0.73	0.39, 1.24
Okanogan County	0.72	0.34, 1.32	1.31	0.63, 2.41
Ferry/Stevens Counties	1.33	0.79, 2.10	0.35	0.07, 1.03
Adams County	0.78	0.56, 1.07	0.92	0.25, 2.34
Total	0.97	0.88, 1.07	0.99	0.83, 1.16

Birth year analyses were also conducted for the two cause of death categories shown to have the greatest excess over expected in the overall analysis (congenital anomalies and conditions of the perinatal period). Table xx shows that for causes attributed to conditions of the perinatal period, the excess in mortality was considerably higher for the 1945-46 birth cohort (SMR = 2.3, 95% CI = 1.7, 3.0). This pattern was not seen for congenital anomalies. For the two causes combined, there was approximately an 87% excess in mortality over expected for the 1945-46 birth cohort that was statistically significant. In comparison, the excess for these two causes for the 1940-44 birth cohort was approximately 37%, and was also statistically significant.

Table Appendix 23-7. Standardized Mortality Ratio (SMR) For Selected Causes of Death, by Birth Year

	1940-1944		1945-1946		Total	
Cause of Death	SMR	95% CI	SMR	95% CI	SMR	95% CI
Congenital Anomalies	1.27	0.87, 1.79	1.03	0.49, 1.89	1.20	0.86, 1.62
Conditions of perinatal period	1.42	1.10, 1.82	2.28	1.67, 3.05	1.69	1.39, 2.04
Congenital Anomalies and conditions of perinatal period	1.37	1.11, 1.67	1.87	1.41, 2.44	1.52	1.28, 1.78
Total Mortality	0.97	0.88, 1.07	0.99	0.83, 1.16	0.97	0.89, 1.06

To further investigate the possibility that the higher than expected mortality might be related to operations at Hanford, additional analyses were conducted according to year of death, classified as before 1945 (beginning of Hanford operations) and 1945 or later. Standardized mortality ratios were calculated for each of the ten major cause of death categories, and for each geostratum, for males and females separately, for the two date of death time periods. Table xx provides the results by cause of death category. For total mortality, there was little difference in the SMRs for deaths before 1945 and for the period from 1945 on (SMR = 1.06 vs. 0.95, respectively), and neither was statistically significant. This pattern was similar in males and females, although the SMR for females was slightly higher in the earlier period (SMR = 1.14) than the later (SMR = 0.91). For congenital anomalies, the SMR for the period prior to 1945 was higher than for the period 1945+ (SMR = 1.46 vs. 0.95), and was higher for both males and females. Similarly, for conditions of the perinatal period, the SMR for the period prior to 1945 was higher than for the period 1945+ (SMR = 1.79 vs. 1.56), and was higher for females (SMR = 2.03 vs. 1.31) but not for males (1.63 vs 1.74).

Table Appendix 23-8. Standardized Mortality Ratio (SMR), by Sex, Cause of Death, and Year of Death

	Year of Death < 1945						Year of Death 1945+					
	Female		Male		Total		Female		Male		Total	
Cause of Death	SMR	95% CI	SMR	95% CI	SMR	95% CI	SMR	95% CI	SMR	95% CI	SMR	95% CI
Infectious/parasitic	1.10	.23, 3.22	2.49	.999, 5.13	1.80	.87, 3.32	.12	.01, .42	.36	.19, .61	.28	.16, .46
Malignant neoplasm	10.78	.27, 59.90	0	--	4.11	.10, 22.85	1.14	.82, 1.54	.84	.56, 1.21	.99	.78, 1.25
Diabetes	28.15	.71, 156.4	0	--	18.08	.46, 100.47	.80	.16, 2.32	.76	.21, 1.95	.78	.31, 1.60
Cardiovascular disease	0	--	0	--	0	--	1.22	.70, 1.98	1.28	.91, 1.76	1.26	.95, 1.65
Pneumonia & influenza	.14	.004, .80	1.20	.60, 2.16	.75	.38, 1.30	.63	.17, 1.61	.36	.07, 1.04	.47	.19, .98
Gastrointestinal disorders	0	--	1.27	.03, 7.07	.81	.02, 4.49	0	--	1.07	.43, 2.21	.65	.26, 1.34
Complications of pregnancy	0	--	0	--	0	--	0	--	0	--	0	--
Congenital anomalies	1.71	.85, 3.05	1.32	.72, 2.21	1.46	.94, 2.16	.63	.20, 1.48	1.20	.62, 2.09	.95	.55, 1.52
Condition in perinatal period	2.03	1.36, 2.92	1.63	1.13, 2.27	1.79	1.38, 2.29	1.31	.75, 2.12	1.74	1.18, 2.49	1.56	1.14, 2.09
External Causes of Injury/Poisoning	1.06	.22, 3.10	.65	.13, 1.90	.80	.30, 1.75	1.21	.85, 1.68	1.15	.94, 1.40	1.17	.98, 1.38
All other causes	.50	.22, .99	.23	.08, .49	.33	.18, .55	.75	.45, 1.18	.71	.46, 1.05	.73	.53, .98
Total	1.14	.86, 1.48	1.01	.79, 1.26	1.06	.89, 1.26	.91	.76, 1.07	.97	.86, 1.09	.95	.86, 1.04

Table xx shows the results of the year of death analyses by geostratum for those who died at under age 5. The excess mortality in the geostratum defined by births in Franklin County was concentrated in the later time period. The SMR for deaths from 1945+ was 2.91 (95% CI = 1.46-5.21), and for deaths before 1945 was 0.73 (95% CI = 0.24 – 1.71). This excess in the later time period was seen in both males and females, and to a greater extent in males. No other geostratum exhibited an appreciable difference in mortality according to year of death category.

Table Appendix 23-9. Standardized Mortality Ratio (SMR), by Sex, Geostrata, and Year of Death, for Those Who Died at Age<5

	Year of Death < 1945						Year of Death 1945+					
	Female		Male		Total		Female		Male		Total	
Geostrata	SMR	95% CI	SMR	95% CI	SMR	95% CI	SMR	95% CI	SMR	95% CI	SMR	95% CI
Richland	1.45	.04, 8.04	.68	.02, 3.77	.92	.11, 3.33	.36	.07, 1.04	.69	.30, 1.35	.55	.27, .98
Pasco/Kennewick	1.56	1.01, 2.30	1.25	.85, 1.77	1.37	1.04, 1.78	.84	.38, 1.58	1.29	.79, 1.99	1.10	74, 1.59
Walla Walla City	.28	.01, 1.53	1.14	.42, 2.48	.79	.32, 1.62	.76	.16, 2.21	.53	.11, 1.56	.62	.23, 1.36
Benton County	1.38	.80, 2.21	.97	.57, 1.53	1.13	.79, 1.58	1.05	.45, 2.07	1.30	.71, 2.18	1.20	.75, 1.81
Franklin County	.74	.09, 2.69	.72	.15, 2.11	.73	.24, 1.71	1.95	.40, 5.70	3.58	1.54, 7.04	2.91	1.46, 5.21
Walla Walla County	.23	.01, 1.29	.63	.17, 1.61	.47	.15, 1.10	.44	.05, 1.58	.60	.16, 1.53	.53	.20, 1.16
Okanogan County	1.05	.13, 3.79	1.09	.23, 3.20	1.08	.35, 2.51	1.92	.52, 4.91	1.03	.21, 3.01	1.40	.56, 2.89
Ferry/Stevens Counties	1.47	.30, 4.31	1.11	.23, 3.23	1.26	.46, 2.75	1.39	.29, 4.06	.32	.01, 1.77	.75	.21, 1.93
Adams County	.79	.26, 1.85	.72	.29, 1.49	.75	.39, 1.31	0	--	.34	.01, 1.90	.20	.005, 1.09
Total	1.14	.86, 1.48	1.01	.79, 1.26	1.06	.89, 1.26	.81	.56, 1.12	1.01	.77, 1.29	.93	.75, 1.13