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MORTALITY

All-Cause Mortality for Diabetics or Individuals with Hyperglycemia Applying for Life Insurance

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Diabetics and individuals with lab results consistent with a diagnosis of diabetes or hyperglycemia were extracted from data covering US residents who applied for life insurance between January 2007 and January 2014. Information about these applicants was matched to the Social Security Death Master File (SSDMF) and another commercially available death source file to determine vital status. Due to the inconsistencies of reporting within the death files, there were two cohorts of death cases, one including the imputed year of birth (full cohort of deaths), and the second where the date of birth was known (reduced cohort of deaths).

The study had approximately 8.5 million person-years of exposure.

Actual to expected (A/E) mortality ratios were calculated using the Society of Actuaries 2008 Valuation Basic Table (2008VBT) select table, age last birthday and the 2010 US population as expected mortality rates. With the 2008VBT as an expected basis, the overall A/E mortality ratio was 3.15 for the full cohort of deaths and 2.56 for the reduced cohort of deaths. Using the US population as the expected basis, the overall A/E mortality ratio was 0.98 for the full cohort of deaths and 0.79 for the reduced cohort. Since there was no smoking status information in this study, all expected bases were not smoker distinct.

A/E mortality ratios varied by disease treatment category and were considerably higher in individuals using insulin. A/E mortality ratios decreased with increasing age and took on a J-shaped distribution with increasing BMI (Body Mass Index). The lowest mortality ratios were observed for overweight and obese individuals. The A/E mortality ratio based on the 2008VBT decreased with the increase in applicant duration, which was defined as the time since initial life insurance application.

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Diabetes is a chronic, progressive and incompletely understood metabolic disease defined by the presence of chronic hyperglycemia.[1,2] Diabetes increases the risk of disabling and life-threatening complications from micro-vascular disease (affecting the kidneys, eyes and limbs) and macro-vascular disease (involving the coronary vascular, cerebrovascular, and peripheral vascular systems).[3] As a result, mortality rates are significantly higher in individuals with diabetes than in those without diabetes, with the majority of deaths due to

cardiovascular disease.[4–13] The global burden of diabetes has risen dramatically over the last two decades, and diabetes is expected to affect more than 500 million adults worldwide by 2030.[14] As diabetes will continue to be routinely encountered by life underwriters in insurance applications, it will be important to examine current diabetes-related mortality trends, patterns and outcomes in the insured population.[15]

The purpose of this research was to determine the mortality of diabetics or hyperglycemic insurance applicants. In addition to exploring the nature of all-cause mortality within the relevant population, another purpose of this research was to determine if data from MIB's database of medical impairments, derived from applications for life insurance, can be reliably matched to death file information and used as a basis for an all-cause mortality study. The impairment chosen was diabetes or a laboratory test result consistent with the diagnosis of diabetes or related conditions as listed in the Methodology section between January 2007 and January 2014.

The data used for this study were contained on the medical impairment database operated by MIB, Group, Inc. MIB is a member cooperative data exchange formed by the North American life insurance industry in 1902. Currently, it is a cooperative of 430 US and Canadian insurance companies. These member companies represent most of the underwritten life insurance activity in the United States and Canada.[16] Since there is no national Canadian death registry, the Canadian applicants were excluded from this study.

The sample used for this study was unique as it represented all of the applicants for life insurance from MIB member companies over 7 years. If an applicant was in the MIB database more than once as they had multiple applications for insurance, then only the oldest record for that applicant was considered for this analysis. This was a large sample for this type of study as it represented over 8.5 million person-years of exposure and between 59,220 and 72,870 deaths. This was the first time that a study of this type had been done where the whole insurance applicant pool had been examined for diabetes or hyperglycemia.

This research was done under the guidance of the Mortality Risk Analysis Committee (MRAC). This Committee is a coordinated multidisciplinary committee of actuaries, medical directors, underwriters and other roles appointed by the senior management of MIB with input from MRAC members. The Committee serves as an advisory group. Its mission is to facilitate and direct research endeavors, focusing on mortality risk relevant to insurance enterprises.[17]

METHODOLOGY

Individuals who applied for life insurance who either had clinically diagnosed diabetes or the following plasma glucose test results posted to the MIB database were included in this study: fasting blood glucose; 2-3 hour postprandial blood glucose; hemoglobin A1c; elevated fructosamine or glycated serum protein; single specimen proteinuria or an intermittent proteinuria finding; constant proteinuria; and albuminuria or microalbuminuria. Individuals with proteinuria or albuminuria were selected only if they were diabetic or hyperglycemic. All impairment information along with diabetes was retained for each applicant.

Applicants between the ages of 25 and 75 inclusive at the time of application were examined in this analysis. Canadian applicants were not considered because there was no standard death file or registry to validate deaths. In cases where there was more than one record on an individual, only the oldest was retained.

The records were first searched against the Social Security Death Master File (SSDMF). The entire SSDMF was used, since this investigation took place prior to restrictions subsequently imposed on the use of recent SSDMF deaths.[18] To more accurately confirm all possible deaths, a second death source file was

used, a database beyond the SSDMF that had more than 3000 sources of death notifications. Deaths had to adequately match at least one database to be included in this study.

Approximately 18.6% of the records in the second death source did not have a date of birth, only age at death. From this, the year of birth was calculated using the age at death and compared with the applicant year of birth. This is a pivotal element of this research: rather than eliminate the death records with the calculated year for date of birth, and potentially underestimate the A/E mortality ratio, the death records were defined as two sets. One set included the deaths of individuals for which the year of birth was calculated (the full cohort of deaths) and a second set removed all these death records (the reduced cohort of deaths). The authors believed this sets a reasonable floor (using the reduced cohort of deaths) and a ceiling (the full cohort of deaths) for the A/E mortality ratio.

Gender was not specified in 71.2% of the applicants. A name algorithm to classify the unknown gender was tested, but it failed to provide consistent results. Therefore, A/E mortality ratios where gender was compared were not part of the analytical results.

When calculating mortality rates, the actual mortality experience was compared with expected mortality, as determined by use of two standard mortality tables: the first was the Society of Actuaries 2008VBT[19] select table, age last birthday and the second was the 2010 US population mortality rates.[20]

The 2008VBT is age, gender, smoking status and duration distinct. In cases where gender or smoking status was unknown, the composite select mortality weighted average mortality rate was used. The weights for this calculation were based on the male/female person-years of experience ratio of known gender applicants (56.4% male, 43.6% female). This statistic is referred to as $Q(VBT)_{x(t)}$, where 'x' is the attained age of the applicant and 't' each applicant duration year.

The US 2010 population mortality rates were adjusted using the formula $Q(US)_x = M_x/(1 + 0.5*M_x)$ where M_x was the central death rate for each age.[20] This adjustment was necessary to make this statistic comparable with the corresponding mortality rate of the 2008VBT, which is the death rate at the end of the age interval. This statistic was weighted by the known gender person-years of exposure.

Person-years of exposure were defined as the time in years from when the applicant first had an impairment reported on the MIB database to January 2014 if the applicant was alive. If the applicant became an observed death, then the person-years of exposure were the number of years between the impairment reported date and the date of death, rounded up to the next integer.

The mortality statistic used in this paper was an actual-to-expected ratio (A/E). The "actual" was the number of observed deaths for the category of interest. The "expected" was a summation of the mortality rates derived from the 2008VBT or the 2010 US population mortality table times each person-year of exposure for each of the applicants. Eight A/E mortality ratios were considered and are summarized in Table 1.

Since the number of person-years of exposure was so large, the confidence bands around the mortality ratios were extremely small. Therefore, no confidence bands were presented and any difference in mortality ratios is assumed to be statistically significant.

The variables considered for this analysis were diabetes/hyperglycemia treatment category, applicant age at application, body mass index (BMI defined as: Weight (lbs)/(Height $(in)^2$ * 703)), and applicant duration (defined as the duration from the impairment reported date to death or January 2014, whichever occurred first).

The levels of diabetes/hyperglycemia treatment categories were:

- Hyperglycemic
- Controlled by Diet
- Use of Oral Medication

Table 1. Comparison of A/E Mortality Ratios by Using Known and Unknown Gender

A/E Mortality Ratio Description	A/E Ratio
Full cohort $Q(VBT)_{x(t)}$ Based on Known Gender	3.16
Full cohort $Q(VBT)_{x(t)}$ Based on Unknown Gender	3.15
Full cohort $Q(US)_x$ Based on Known Gender	0.98
Full cohort $Q(US)_x$ Based on Unknown Gender	0.98
Reduced cohort $Q(VBT)_{x(t)}$ Based on Known Gender	2.56
Reduced cohort $Q(VBT)_{x(t)}$ Based on Unknown Gender	2.56
Reduced cohort $Q(US)_x$ Based on Known Gender	0.79
Reduced cohort $Q(US)_x$ Based on Unknown Gender	0.79

- Use of Insulin
- Treatment Unknown

Applicant Age ranges were:

- 25–34
- 35–44
- 45–54
- 55–64
- 65–75

BMI was categorized as follows: Underweight (<18.5), Normal Weight (18.5 to <25), Overweight (25 to <30), Obese (30 to <35), and Morbid Obesity (35+). Applicant duration was defined in years from the time of the first posting to the MIB database and had the values of: 1, 2, 3, 4, 5, 6 and 7.

RESULTS

This study had 8,518,178 person-years of exposure with 72,870 deaths. After removing the calculated birth year records from the secondary death source, the number of deaths decreased to 59,220 and the person-years of exposure increased to 8,533,159. This increase in person-years exposure was due to the person-years exposure being calculated to the end of the study instead of to the time at death, for each death removed from the study.

The overall A/E ratio based on the 2008VBT select expected basis was 3.16 when gender was used along with the composite, and 3.15 when the composite was used throughout for the full cohort of deaths (Table 1). Using the reduced cohort of deaths reduced this statistic to 2.56. The A/E ratios based on US population mortality were 0.98 for the full cohort of deaths, and 0.79 for the reduced cohort.

The A/E mortality ratios calculated using only a composite mortality rate, and those calculated with a gender specific mortality rate where gender was known with a composite rate used elsewhere were identical. Thus, A/E mortality ratios quoted in the remainder of this study use the composite A/E mortality ratio.

Mortality by diabetes treatment category and applicant age is summarized in Table 2 for the person-years of exposure.

The largest group by person-years exposure in the study had a clinical diagnosis of diabetes controlled by use of oral medication (47.1%). Approximately 25% were considered diabetic but were considered hyperglycemic. These cases had an elevated plasma glucose test, but no indication of an extant diagnosis of diabetes in the data. Insulin treated diabetics had 13.5% of the total person-years of exposure, while diet-controlled diabetics contributed 6.9%. Approximately 7.6% were clinically diagnosed diabetics, but could not be further categorized (form of treatment was unknown).

The clinically diagnosed diabetics had increasing person-years of exposure for age 55 to 64, with a consistent decrease from 65 to 75. The hyperglycemic group had a different profile in that they had more person-years exposure in the younger ages and fewer in the older.

The A/E mortality ratios by diabetes category and applicant age are shown in Table 3.

The A/E mortality ratios were higher for individuals using oral medication than for those treated with diet alone. The hyperglycemic A/E mortality ratios were slightly lower than that of the diabetics controlled by diet.

Table 2. Exposure by Diabetes Treatment Category and Applicant Age

Diabetes Treatment Category	Applicant Age	Person Years of Exposure	Percent	Full Cohort of Deaths	Percent	Revised Person Years of Exposure	Percent	Reduced Cohort of Deaths	Percent
Hyperglycemic	25 – 34	144,473	6.8	128	1.6	144,522	6.8	90	1.6
	35 – 44	479,217	22.5	712	9.0	479,492	22.5	501	8.7
	45 – 54	729,370	34.4	1,970	25.0	730,134	34.3	1,344	23.4
	55 – 64	572,664	26.9	3,014	38.2	573,515	27.0	2,191	38.1
	65 – 75	199,707	9.4	2,070	26.2	200,083	9.4	1,623	28.2
	All Ages	2,125,431	100.0	7,894	100.0	2,127,746	100.0	5,749	100.0
Controlled by Diet	25 – 34	24,008	4.1	49	1.3	24,029	4.1	35	1.2
	35 – 44	84,151	14.4	180	4.7	84,204	14.4	140	4.7
	45 – 54	163,568	27.9	628	16.5	163,766	27.9	471	15.8
	55 – 64	198,876	34.0	1,400	36.8	199,274	34.0	1,067	35.7
	65 – 75	114,751	19.6	1,545	40.7	115,009	19.6	1,271	42.6
	All Ages	585,354	100.0	3,802	100.0	586,282	100.0	2,984	100.0
Use of Oral Medication	25 – 34	138,715	3.5	227	0.7	138,797	3.4	179	0.7
	35 – 44	545,718	13.6	1,344	4.0	546,088	13.6	1,053	3.9
	45 – 54	1,145,625	28.6	5,511	16.3	1,147,321	28.6	4,202	15.6
	55 – 64	1,401,179	34.9	12,590	37.3	1,404,240	34.9	9,885	36.7
	65 – 75	779,075	19.4	14,052	41.7	781,429	19.5	11,581	43.1
	All Ages	4,010,312	100.0	33,724	100.0	4,017,875	100.0	26,900	100.0
Use of Insulin	25 – 34	109,564	9.5	347	1.8	109,613	9.5	303	1.8
	35 – 44	189,594	16.5	1,088	5.6	189,821	16.4	908	5.3
	45 – 54	295,582	25.7	3,577	18.2	296,169	25.7	3,047	18.0
	55 – 64	350,952	30.4	7,199	36.7	352,044	30.5	6,176	36.5
	65 – 75	205,744	17.9	7,397	37.7	206,588	17.9	6,495	38.4
	All Ages	1,151,436	100.0	19,608	100.0	1,154,235	100.0	16,929	100.0
Treatment Unknown	25 – 34	48,991	7.6	144	1.8	49,015	7.6	126	1.9
	35 – 44	125,842	19.5	641	8.2	125,954	19.5	548	8.2
	45 – 54	201,050	31.1	1,848	23.6	201,432	31.1	1,543	23.2
	55 – 64	191,941	29.7	2,943	37.5	192,509	29.7	2,486	37.3
	65 – 75	77,821	12.1	2,266	28.9	78,111	12.1	1,955	29.4
	All Ages	645,645	100.0	7,842	100.0	647,021	100.0	6,658	100.0
Total	25 – 34	465,751	5.5	895	1.2	465,976	5.5	733	1.2
	35 – 44	1,424,522	16.7	3,965	5.4	1,425,559	16.7	3,150	5.3
	45 – 54	2,535,195	29.8	13,534	18.6	2,538,821	29.8	10,607	17.9
	55 – 64	2,715,612	31.8	27,146	37.3	2,721,583	31.8	21,805	36.8
	65 – 75	1,377,098	16.2	27,330	37.5	1,381,220	16.2	22,925	38.8
	All Ages	8,518,178	100.0	72,870	100.0	8,533,159	100.0	59,220	100.0

The A/E Mortality Ratios of insulin dependent diabetics were between 2 and 3 times those of the other categories of diabetes where the degree of diabetes was defined. Clinically diagnosed diabetics under the age of 54 consistently had the highest mortality ratios with the ratios decreasing as the cohort ages. The hyperglycemic applicants also had decreasing mortality ratios as the cohort ages.

The person-years of exposure by BMI is summarized on Table 4.

Approximately 30% of the person-years of exposure had a height and weight provided. Of the person-years of exposure where BMI

Table 3. A/E Mortality Ratios by the Diabetes Treatment Category and Applicant Age

Diabetes Treatment Category	Applicant Age	Full cohort A/E Q(VBT)x(t)	Reduced cohort A/E Q(VBT)x(t)	Full cohort A/E Q(US)x	Reduced cohort A/E Q(US)x
Hyperglycemic	25 – 34	2.89	2.03	0.75	0.53
	35 – 44	2.76	1.94	0.69	0.48
	45 – 54	2.23	1.52	0.55	0.37
	55 – 64	1.86	1.35	0.54	0.39
	65 – 75	1.40	1.10	0.49	0.38
	All Ages	1.85	1.34	0.54	0.39
Controlled by Diet	25 – 34	6.54	4.67	1.71	1.22
	35 – 44	3.80	2.96	0.96	0.75
	45 – 54	2.98	2.23	0.75	0.56
	55 – 64	2.27	1.73	0.68	0.52
	65 – 75	1.68	1.38	0.60	0.49
	All Ages	2.11	1.65	0.67	0.53
Use of Oral Medication	25 – 34	5.23	4.12	1.36	1.07
	35 – 44	4.36	3.41	1.10	0.86
	45 – 54	3.75	2.85	0.94	0.72
	55 – 64	2.93	2.30	0.88	0.69
	65 – 75	2.27	1.87	0.81	0.66
	All Ages	2.74	2.18	0.87	0.69
Use of Insulin	25 – 34	10.31	8.99	2.72	2.37
	35 – 44	10.61	8.84	2.68	2.23
	45 – 54	9.66	8.21	2.40	2.04
	55 – 64	6.81	5.83	2.01	1.72
	65 – 75	4.59	4.02	1.61	1.41
	All Ages	6.18	5.32	1.92	1.65
Treatment Unknown	25 – 34	9.43	8.25	2.48	2.17
	35 – 44	9.09	7.77	2.32	1.98
	45 – 54	7.17	5.98	1.82	1.52
	55 – 64	5.07	4.27	1.52	1.28
	65 – 75	3.63	3.12	1.30	1.12
	All Ages	5.06	4.29	1.56	1.32
Total	25 – 34	6.21	5.09	1.62	1.33
	35 – 44	5.04	4.00	1.27	1.01
	45 – 54	4.24	3.32	1.06	0.83
	55 – 64	3.33	2.67	0.99	0.79
	65 – 75	2.52	2.11	0.90	0.75
	All Ages	3.15	2.56	0.98	0.79

was known, approximately two-thirds were in the Morbid Obesity category.

The A/E mortality ratios for the full cohort of deaths increased with increasing BMI for those overweight, obese, and morbidly obese (Table 5). The A/E mortality ratio based on the 2008VBT increased from 2.60 to 3.81 from overweight to morbid obesity. The lowest A/E mortality ratio based on the 2010 US population was 0.78 for the overweight cases, increasing to 1.13 for the morbid obesity category.

The A/E mortality ratios by BMI are shown in Table 5.

The normal weight and underweight individuals had A/E mortality ratios far in excess of the other BMI categories in the study. The group with unknown BMI had A/E mortality ratios very close to the overall mortality of the entire cohort.

A summary of the person-years of exposure by Applicant Duration is found on Table 6. Approximately 41% of the deaths occurred

Table 4. Exposure by Body Mass Index

BMI Description	Person Years of Exposure	Percent	Full Cohort of Deaths	Percent	Revised Person Years of Exposure	Percent	Reduced Cohort of Deaths	Percent
Underweight	4,100	0.1	131	0.2	4,119	0.1	118	0.2
Normal Weight	9,087	0.1	100	0.1	9,105	0.1	88	0.2
Overweight	35,370	0.4	218	0.3	35,425	0.4	174	0.3
Obese	724,809	8.5	4,934	6.8	726,074	8.5	3,841	6.5
Morbid Obesity	1,818,603	21.3	14,569	20.0	1,821,751	21.3	11,759	19.9
No Height/ Weight	5,926,209	69.6	52,918	72.6	5,936,685	69.6	43,240	72.9
Total	8,518,178	100.0	72,870	100.0	8,533,159	100.0	59,220	100.0

in the first two durations. This may not be surprising given the distribution of exposure by duration.

The A/E mortality ratios based on the 2008VBT showed a consistent downward trend over the various durations (Table 7).

The mortality pattern based on the expected deaths of the US population increased from the first duration to the last, from 0.81 to 1.15. Using the reduced cohort of deaths, the A/E mortality ratios increased for durations 1 to 4, and then flattened hovering around 0.82 to 0.86 for durations 5 through 7.

DISCUSSION

This paper was an all-cause mortality study for insurance applicants who had an indication of clinical diabetes or hyperglycemia reported to the MIB database. Due to the ambiguity in some of the information used to match the death records, the results were presented using the full cohort of deaths and a reduced cohort of deaths. The authors believed this essentially set a reasonable floor (using the reduced cohort of deaths) and a ceiling (the full cohort of deaths) for the A/E mortality ratio.

The results of this study demonstrated the impact that underwriting has on mortality experience for life insurance. Previous work by Milano et al[15] on policies issued to diabetics demonstrated an overall mortality ratio of 1.71, based on the 2001VBT, gender and smoker distinct. Even though a direct comparison of mortality results cannot be made due to the use of different expected bases as well as the difference between insurance applied for and insurance issued, the order of magnitude of the difference between this

Table 5. A/E Mortality Ratios by Body Mass Index

BMI Description	Full Cohort A/E Q(VBT)x(t)	Reduced Cohort A/E Q(VBT)x(t)	Full Cohort A/E Q(US)x	Reduced Cohort A/E Q(US)x
Underweight	10.18	9.11	3.21	2.87
Normal Weight	4.07	3.58	1.26	1.11
Overweight	2.60	2.07	0.78	0.62
Obese	2.92	2.27	0.88	0.68
Morbid Obesity	3.81	3.07	1.13	0.91
No Height/Weight	3.03	2.47	0.95	0.77
Total	3.15	2.56	0.98	0.79

Table 6. Exposure by Applicant Duration

Applicant Duration	Person Years of Exposure	Percent	Full Cohort of Deaths	Percent	Revised Person Years of Exposure	Percent	Reduced Cohort of Deaths	Percent
1	2,335,968	27.5	14,533	20.0	2,340,319	27.5	12,309	20.8
2	1,944,542	22.8	15,187	20.8	1,948,470	22.8	12,637	21.3
3	1,562,077	18.3	13,917	19.1	1,564,919	18.3	11,528	19.6
4	1,194,454	14.0	12,225	16.8	1,196,443	14.0	9,856	16.6
5	831,292	9.8	9,135	12.5	832,689	9.8	7,016	11.8
6	487,217	5.7	5,753	7.9	487,691	5.7	4,279	7.2
7	162,628	1.9	2,120	2.9	162,628	1.9	1,595	2.7
Total	8,518,178	100.0	72,870	100.0	8,533,159	100.0	59,220	100.0

study and Milano's work suggest an underwriting selection on the mortality for the placed policies.

The 0.98 or 0.79 A/E mortality ratio based on the 2010 US Population implies that diabetic or hyperglycemic life insurance applicants demonstrate lower mortality than the general population. Many other studies have demonstrated that diabetes is associated with higher all-cause mortality in the general population. Therefore, the mortality ratios below 1.00 are taken to indicate a bias toward healthier diabetics, rather than a favorable effect of diabetes on mortality. This bias is likely the result of the self-selection of life insurance applicants – who are essentially indicating a baseline threshold of health by having the ability to attempt to obtain a commercial financial product. Since life insurance is a non-essential product, individuals who can afford it are also not likely to be in lower socioeconomic strata, which are known to experience higher baseline mortality rates.[21]

The A/E mortality ratios did not change at all whether using the gender expected as a basis where known or using the composite throughout. Contributing factors to this were the small change in the expected mortality rates from known gender to composite and the relatively small percentage of individuals where gender was known (approximately 29%).

Mortality ratios from this study were compared with those of the National Vital Statistics Reports for the same years of this study. The National Vital Statistics Reports provided annual mortality rates per 100,000 lives. For comparative purposes, age adjusted rates were used to account for the changing age demographics over the years. To compare, the statistics presented in this paper had to be converted to rates per 100,000 lives.

Table 7. A/E Mortality Ratios by Applicant Duration

Applicant Duration	Full Cohort A/E Q(VBT)x(t)	Reduced Cohort A/E Q(VBT)x(t)	Full Cohort A/E Q(US)x	Reduced Cohort A/E Q(US)x
1	4.45	3.76	0.81	0.68
2	3.59	2.97	0.94	0.78
3	3.08	2.54	1.01	0.83
4	2.86	2.30	1.09	0.87
5	2.60	1.99	1.10	0.84
6	2.42	1.79	1.10	0.82
7	2.35	1.77	1.15	0.86
Total	3.15	2.56	0.98	0.79

When this calculation was made, the overall mortality rate for the full cohort of deaths was 855.5 per 100,000. The mortality rate for the reduced cohort of deaths was 694.0 per 100,000. The National Vital Statistics Reports[22-28] provided the following age adjusted mortality rates over the study years: 2013 - 731.9; 2012 - 732.8; 2011 – 740.6; 2010 – 747.0; 2009 – 741.1; 2008 – 758.3; 2007 – 760.2.

Campbell et al[29] followed a prospective cohort of self-reported diabetics, part of the over 1 million US adults without cancer at baseline, who were enrolled in the Cancer Prevention Study-II from 1982 to 2008. When they controlled for age, BMI and other variables they reported that the multivariable adjusted relative risk for males was 1.73 and for females was 1.90. The relative risk for diabetic and hyperglycemic insurance applicants that came the closest to this were ratios of $Q(VBT)_{x(t)}$ (based on the 2008VBT) and $Q(US)_x$ (based on the 2010 US Population) for those with any form of diabetes plus the unknown divided by those with only hyperglycemia. For the full and reduced cohorts of deaths, the respective ratios were 1.53 and 1.64 based on the 2008VBT and 1.64 and 1.75 based on the US population. Even though our study did not control for age or BMI, these ratios were close to those found in Campbell et al, but ultimately could be lower if the hyperglycemic cases had a history of clinical diabetes which was not reported to MIB.

Due to the inconsistency of reporting within the death files, when comparing death cases to the applicant record, much work had to be done to determine if a given applicant case actually represented a death for study purposes. Independent work done outside of this research, using a cohort of data from an MIB member-company where Social Security Number and the death of the case were known, determined that when the Surname and Date of Birth matched exactly, the sensitivity was approximately 97%. When the match on date of birth was fuzzy (as in the imputed year of birth from the other death source), the sensitivity was much lower. This presented a problem for this analysis because if all the imputed year of birth deaths were removed, then the death ratio would be understated. This was why two sets of A/E mortality ratios were provided. The true A/E mortality ratio for this cohort was expected to be somewhere between these two.

McEwen et al[30] provided an analysis of the work they did on matching death records. They verified deaths by matching gender, date of birth and Social Security Number (approximately 52% of the records in their study had this information on file) to the National Death Index (NDI). They found that the sensitivity ranged from approximately 87% to 98%. If Social Security Number was not present, then matching by a combination of identities correctly identified between 83% and 92% of the dead individuals.

The sensitivity of the methodology of matching of deaths to applicants that was used for this paper was comparable to McEwen's work for the reduced cohort of deaths. When the full cohort of deaths were included but assumed to be falsely matched, the sensitivity fell to approximately 80%. However, many records in the full cohort of deaths likely matched the correct person, which would put the overall sensitivity of the death matches close to those of McEwen et al.

Further work on the matching of known death cases to the Social Security Death Master File alone was done by Ashley et al[31] in 2012. In this article the authors pointed out that overall they could only match approximately 75% of the known deaths to the Social Security Death Master File. They found that the match rate varied depending on the age of death of the individual. This low match rate for the Social Security Death Master File was the main reason that an additional death file source was used for this paper.

When examining the diabetes treatment categories, a consistent three-fold increase in the A/E mortality ratios was seen between the 2008VBT and the 2010 population. The hyperglycemic individuals had lower mortality ratios to the diabetics controlled by diet. As expected,

the mortality increased for diabetics using oral medication as compared with those controlled by diet alone. The A/E mortality ratio doubled for the insulin dependent diabetics over those using oral medication.

The A/E mortality ratios based on the 2008VBT by applicant age were slightly more than twice as high for ages 25 to 34 as they were for those 65 to 75. The ratios steadily declined as the ages of the applicants increased. One explanation for this phenomenon was that when diabetes was diagnosed in a younger person, it was more severe. This is consistent with the fact that type 1 (formally known as "insulin dependent") diabetes is associated with higher rates of complications.

A similar trend existed for the A/E mortality ratios based on the 2010 US population, with a declining ratio for older applicants. The differences between the 2008VBT and 2010 US population A/E mortality ratios were larger in the younger cohorts (the 2008VBT about 4 times the population) than in the older group (2008VBT approximately 2.7 times the population).

Even though there were much fewer deaths and person-years exposure for the lower BMI individuals than the obese and morbid obese, there is enough information to make a valid conclusion. The main conclusion is that the J shaped curve generated by the A/E mortality ratios by Body Mass Index seemed counterintuitive in that the normal weight individuals had a higher mortality rate than those who were overweight and obese. However, this phenomenon was observed in a study by Tobias et al[32] where, among type 2 diabetics, the Hazard Ratio for those with a BMI between 18.5 and 22.4 was 1.29 as compared with the ratio of 1.00 for the reference BMI of 22.5 to 24.9, with slight increases in the ratios to 1.12 and 1.09 for those with BMIs between 25.0 to 27.4 and 27.5 to 29.9, respectively. Another study that evaluated of all-cause mortality, using the BMI of 30 to 34.9 as a reference group, demonstrated that there was an increase in the Hazard Ratio both in the lower and upper BMI regions.[33] This phenomenon was further discussed and referenced in an editorial from the journal *Circulation*[34] using administrative data from the Louisiana State University Health Care Services Division where the author referred to this phenomenon as the "Obesity Paradox."

Applicant duration mortality ratios based on the 2008VBT showed a steady decline for increasing duration. This may occur because expected death rates were increasing faster than the actual death rates.

The application duration mortality ratio based on the US population expected deaths for the full cohort of deaths increased for increasing duration. This is the reverse of the morality ratio change based on the 2008VBT, which implies that the actual death rate was increasing faster than the expected. The reduced cohort of deaths had an inconsistent pattern, increasing from duration 1 to duration 4 and somewhat leveling off for durations 5 to 7.

Topics of further research for diabetes might include: introducing a cohort of individuals without any known impairments to compare to the diabetics, calculate hazard ratios; assessing the relationship between face amount applied for and diabetes mortality; examining the mortality effect of diabetes along with coronary disease; and determining the sensitivity and specificity of correctly matching individuals to a death registry.

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