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MORTALITY

2014 CRL Blood Pressure Study of Life Insurance Applicants

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Objective.—Define the relative mortality risk by systolic (SBP) and diastolic blood pressure (DBP) in a relatively healthy cohort split by age and sex with adjustment for smoking status, other findings and admitted heart disease history.

Method.—Blood pressure (BP in mm Hg), build, laboratory studies and limited medical history are collected when people apply for individual life insurance. Information on 2,472,706 applicants tested by Clinical Reference Laboratory from 1993 to 2007 was utilized with follow-up for vital status using the September 2011 Social Security Death Master File identifying 31,033 deaths. Data was analyzed by SBP and DBP split by age and sex accounting for smoking and for BMI, urine protein/creatinine ratio and history of heart disease in a Cox multivariate survival analysis. Separate analysis by admitted hypertension history was also conducted. Results are presented by SBP and DBP for 4 age-sex groups with and without added covariates beyond age and smoking status.

Results.—Relative mortality progressively increased by SBP level from the 90 to 119 band (down to 80 in younger women) upward with little additional impact by DBP. Addition of covariates beyond age and smoking resulted in a 5% to 10% reduction in relative risk.

Although high DBP had limited impact, a pulse pressure/SBP ratio $>½$ identified 1% of applicants at high mortality risk, with little difference in risk for ratios $\leq ½$. Hypertension history with current BP control was associated with a 10% to 25% increase in relative mortality risk as compared to those with similar BP but no such history.

Conclusion.—Increasing SBP is closely associated with increasing relative mortality, starting from the lowest SBP. Increasing DBP has little additional impact, but a pulse pressure/SBP ratio $>½$ is a potent marker of increased risk as well. Accounting for build and other laboratory findings reduces risk modestly. A history of hypertension with current control increases risk.

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Blood pressure (abbreviated as BP and expressed in mm Hg) has been an important component of insurance risk assessment for over a century. Several BP mortality studies have been performed using insured lives; the two most recent examples

are the 1979 Build and Blood Pressure Study and the 2003 Swiss Re Blood Pressure Study.[1,2] However, that data is aging and, by necessity, excludes those insurance applicants not becoming or remaining insured.

Many general population studies have addressed blood pressure and mortality, but the more recent have tended to focus on the superiority of one metric or measurement approach (systolic, diastolic, mean arterial or pulse pressure) or focus on particular ages, ethnicity or BP trends over time rather than present a comprehensive table of mortality ratios by age, sex and blood pressure level.

Finally, the question is unsettled as to the relative mortality risk of those who achieve ''normal'' blood pressures by treatment vs those who come by them naturally, with different studies using different parameters coming to differing conclusions.[3]

Fortunately, sufficient blood pressure data on insurance applicants with mortality follow-up is now available in conjunction with data on build, admitted hypertension and heart disease histories, and laboratory values to better assess the relative all-cause mortality risk for various systolic and diastolic blood pressure combinations.

METHODS

As part of the individual life insurance application process in the United States, urine and blood samples are routinely collected by an examiner and sent for testing to one of two laboratories including Clinical Reference Laboratory (CRL), with which the authors are affiliated. The samples are processed in an automated fashion, and the results are forwarded to the insurer requesting the testing. More recently, physical measurements (height, weight and BP) obtained by the examiner may be transmitted through the laboratory to the insurer with the laboratory results. On the CRL laboratory authorization form signed by the applicant, history questions are asked allowing ''yes'' or ''no'' answers, including: ''Do you have a history of heart disease?'' and ''Do you have a history of hypertension?''

We studied 2,472,706 insurance applicants (31,033 deaths) ages 18 to 89 tested at CRL between 1993 and 2007 with height and weight measurements available (few available prior to 2001). All applicants with systolic blood pressures (SBP) between 90 and 199 and diastolic blood pressures (DBP) between 50 and 120 were included; 0.7% were outside of those limits, most of whom were younger females with SBP of 80 to 89 (a group discussed separately below). Follow-up for vital status was conducted by use of the September 2011 Social Security Death Master File. Match was by Social Security number, name and date of birth. Partial matches were manually reviewed; if the only disparity appeared to be probable name misspelling or transposition of dates, these applicants were included as well. The median duration of follow-up was 7 years (range 0 to 18).

Relative mortality risk was calculated by Cox regression analysis using IBM SPSS version 22. Preliminary analysis (not shown) included additional age splits as well as a split by smoking status, but none of these analyses showed consistent differences in resulting mortality ratios while generating wide confidence intervals for some bands because of low numbers of deaths. Because multiple studies had already determined that SBP was typically the strongest predictor of BP risk, we used that as the primary measure with subcategories based on DBP.

The base analyses were split by sex and age 18 to 59 and 60 to 89 with age and smoking (defined as urine cotinine >200 ng/mL indicating use of tobacco or nicotine delivery device) also included as covariates. Additional analysis labeled ''covar=additional'' included age- and sex-adjusted mortality risk scores for body mass index (BMI) and for urine protein/creatinine ratio (urine p/c) and a simple positive/negative for history of heart disease as covariates. This

Table 1. Cumulative Distribution of BP Values by Four Age-Sex Groups

Systolic BP (mm Hg)	Diastolic BP (mm Hg)	Age 18 to 59		Age 60 to 89		Total
		Female	Male	Female	Male	
90 to 119	50 to 59	4.6%	1.1%	1.5%	0.8%	2.5%
	60 to 69	38.1%	14.6%	14.6%	8.8%	23.8%
	70 to 79	67.3%	39.6%	30.4%	22.2%	49.8%
	80 to 89	72.3%	46.3%	33.2%	25.1%	55.5%
	90 to 120	72.4%	46.4%	33.2%	25.1%	55.6%
120 to 124	50 to 59	72.4%	46.4%	33.4%	25.2%	55.7%
	60 to 69	74.0%	48.4%	36.5%	27.8%	57.5%
	70 to 79	80.7%	59.0%	46.6%	37.8%	66.5%
	80 to 89	86.1%	69.4%	52.7%	45.0%	74.6%
	90 to 120	86.2%	69.6%	52.7%	45.1%	74.8%
125 to 129	50 to 59	86.2%	69.6%	52.8%	45.1%	74.8%
	60 to 69	86.6%	70.3%	54.4%	46.5%	75.4%
	70 to 79	89.0%	74.9%	61.0%	53.4%	79.3%
	80 to 89	91.7%	80.8%	65.6%	59.4%	83.9%
	90 to 120	91.8%	81.1%	65.7%	59.5%	84.1%
130 to 139	50 to 59	91.8%	81.1%	65.8%	59.6%	84.1%
	60 to 69	92.0%	81.5%	67.8%	61.3%	84.5%
	70 to 79	93.7%	85.1%	76.3%	70.8%	87.7%
	80 to 89	97.7%	94.7%	87.8%	85.9%	95.3%
	90 to 120	98.2%	95.9%	88.4%	86.9%	96.2%
140 to 149	50 to 59	98.2%	95.9%	88.4%	86.9%	96.2%
	60 to 69	98.2%	95.9%	88.9%	87.2%	96.3%
	70 to 79	98.4%	96.3%	90.8%	89.1%	96.7%
	80 to 89	99.0%	97.7%	94.6%	93.7%	98.0%
	90 to 120	99.4%	98.8%	95.6%	95.2%	98.8%
150 to 159	50 to 59	99.4%	98.8%	95.6%	95.2%	98.8%
	60 to 69	99.4%	98.8%	95.7%	95.3%	98.8%
	70 to 79	99.4%	98.9%	96.2%	95.8%	98.9%
	80 to 89	99.6%	99.1%	97.4%	97.1%	99.1%
	90 to 120	99.8%	99.6%	98.1%	98.1%	99.5%
160 to 199	50 to 59	99.8%	99.6%	98.1%	98.1%	99.5%
	60 to 69	99.8%	99.6%	98.2%	98.1%	99.5%
	70 to 79	99.8%	99.6%	98.5%	98.3%	99.6%
	80 to 89	99.8%	99.7%	99.2%	99.0%	99.7%
	90 to 120	100.0%	100.0%	100.0%	100.0%	100.0%

accounts for information that is often evaluated separately at the time of insurance underwriting or clinical evaluation. Those denying a heart disease history (66.5%) and not answering (32.6%) were combined as ''negative.'' Because BMI and urine p/c have a variable impact on relative mortality by age and sex, rather than use the values, the independent excess mortality risk (score) associated with those values (taken from previous research by the authors) was included as a covariate instead.[4,5]

RESULTS

Table 1 includes the cumulative distribution of SBP and DBP values by age and sex. Approximately 1.2% of females age <60 and <0.2% of the other age-sex groups had SBP <90 with most in the 80 to 89 range (and were excluded from Tables 1 to 6).

Tables 2 to 5 show the distribution by vital status and the relative mortality with 95% confidence intervals for each of the 4 age-sex combinations for bands of SBP from 90 to 199 and DBP from 50 to 120. The reference group across Tables 2 to 5 is a SBP of 120 to 124 with DBP of 70 to 79. Diastolic bands of 50 to 59 and 60 to 69 were combined for SBP bands 140+ in Tables 2 to 5 to provide narrower 95% confidence intervals. For those cells with <5 deaths (eg, lowest diastolic band), the mortality ratio is not shown (''n/a'').

In addition to the results shown, relative mortality in the excluded SBP 80 to 89 band (combining all diastolic values) was examined relative to the same reference band as above. Meaningful results were available only for females age 18 to 59 where the MR using smoking and age covariates was 0.76 and with the additional covariates was 0.80 (data not shown), which were identical to results for the SBP 90 to 119 band.

Relative risk increased as SBP increased, but most diastolic values within each systolic category had similar mortality risk except for the lowest diastolic values (highest pulse pressure) where risk was usually substantially greater. The relationship of mortality risk associated with pulse pressure (SBP minus DBP) is explored in Figure 1 as a percentage of SBP rather than as an absolute value. Mortality ratios were generated for groups split by age 60 and by SBP 130 with age, sex, smoking and risk associated with BMI, urine p/c and heart disease history included as covariates. For subjects in pulse pressure bands ≤½ SBP, relative mortality was very similar but for the 1% of applicants >½ SBP, risk increased steeply.

Table 6 is a comparison of the relative risk between those who admitted and those who denied a history of hypertension (excluding the 32.6% not answering the question). To ensure narrow 95% confidence intervals, age and sex were included as covariates rather than splitting the analysis. Additionally, DBP was only split into <90 and ≥90 bands. In an adjusted analysis (including age, sex, smoking, BMI, urine p/c and heart disease history), a hypertension history increased the risk for SBP <130 by ≈25%, for SBP 130 to 139 by ≈10%, and for SBP >139 only minimally when compared to those who self-reported no hypertension. The same analysis (data not shown) limited to age 50+ had almost identical results.

DISCUSSION

When compared to the 2003 Swiss Re study of insured lives, which had a median SBP of 122 (mean of 124), with a 95th percentile of 148, our applicant population had a lower median of 118 and 95th percentile of 138. This may represent improved BP control, but the earlier study also had 79% males vs our data with 59% males, who (as expected) have higher BP values. For NHANES 2001 to 2008 general population data, the mean SBP was 124 for males and 121 for females.[6] Our mean SBP of 117 was lower, suggesting self-selection or better blood pressure control for insurance applicants. The prevalence of hypertension (defined as treatment or BP >140/90) in the general population is stable, but the percentage of those with BP control is increasing.[7] This might be expected to result in lower mean SBP values for both the more recent general and insurance applicant populations.

In Tables 2 to 5, there is a modest but consistent 5% to 10% reduction in the mortality ratios associated with SBP level after also accounting for BMI, urine p/c and admitted heart disease history in addition to age and smoking. A roughly similar further reduction was observed when the mortality risk associated with all of the laboratory studies was added as a covariate (not shown).

Table 2. Relative Mortality by BP for Females, age 18 to 59, Accounting for Age and Smoking With and Without Additional Covariates

Systolic BP	Vital status		Covar=age+smoker			Covar=additional		
90 to 119			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	45,974	137	0.74	0.61	0.90	0.78	0.64	0.96
60 to 69	333,449	1,137	0.75	0.67	0.85	0.80	0.71	0.89
70 to 79	290,122	1,232	0.79	0.71	0.89	0.82	0.73	0.92
80 to 89	49,484	290	0.96	0.82	1.12	0.97	0.83	1.13
90 to 120	637	2	n/a	n/a	n/a	n/a	n/a	n/a
120 to 124			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	558	5	1.53	0.64	3.70	1.50	0.62	3.61
60 to 69	15,550	77	0.77	0.60	0.98	0.78	0.61	1.00
70 to 79 (ref)	*66,451*	*480*	*1.00*			*1.00*		
80 to 89	53,621	385	0.99	0.86	1.14	0.96	0.84	1.11
90 to 120	959	7	1.20	0.57	2.53	1.15	0.55	2.43
125 to 129			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	165	1	n/a	n/a	n/a	n/a	n/a	n/a
60 to 69	3,876	34	1.07	0.74	1.55	1.05	0.73	1.52
70 to 79	23,562	188	0.93	0.78	1.11	0.90	0.76	1.08
80 to 89	26,523	265	1.20	1.03	1.41	1.15	0.98	1.34
90 to 120	1,036	10	1.34	0.69	2.60	1.25	0.64	2.41
130 to 139			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	110	3	n/a	n/a	n/a	n/a	n/a	n/a
60 to 69	2,084	41	1.94	1.39	2.71	1.86	1.33	2.59
70 to 79	16,676	212	1.21	1.02	1.43	1.13	0.96	1.34
80 to 89	39,423	518	1.28	1.12	1.46	1.17	1.03	1.34
90 to 120	4,468	55	1.46	1.10	1.95	1.28	0.96	1.71
140 to 149			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	301	6	2.69	1.20	6.01	2.38	1.06	5.33
70 to 79	1,530	29	1.49	1.01	2.20	1.37	0.93	2.03
80 to 89	6,065	118	1.51	1.22	1.87	1.30	1.05	1.61
90 to 120	4,202	71	1.69	1.31	2.19	1.43	1.11	1.85
150 to 159			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	62	1	n/a	n/a	n/a	n/a	n/a	n/a
70 to 79	231	10	2.59	1.28	5.20	2.23	1.11	4.50
80 to 89	1,155	42	2.40	1.72	3.34	2.05	1.47	2.87
90 to 120	1,977	50	1.86	1.34	2.57	1.45	1.04	2.00
160 to 199			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	119	1	n/a	n/a	n/a	n/a	n/a	n/a
70 to 79	187	6	3.46	1.55	7.75	2.89	1.29	6.48
80 to 89	461	19	2.68	1.67	4.30	2.14	1.33	3.44
90 to 120	1,600	63	3.06	2.34	4.01	2.30	1.75	3.02

n/a = Number of deaths <5

Table 3. Relative Mortality by BP for Males, Age 18 to 59, Accounting for Age and Smoking With and Without Additional Covariates

Systolic BP	Vital status		Covar=age+smoker			Covar=additional		
90 to 119			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	13,847	134	1.30	1.08	1.56	1.32	1.10	1.59
60 to 69	174,530	1,160	0.86	0.79	0.93	0.88	0.81	0.95
70 to 79	322,612	2,334	0.89	0.83	0.95	0.90	0.84	0.97
80 to 89	86,302	706	0.93	0.84	1.02	0.94	0.85	1.03
90 to 120	1,185	7	0.58	0.26	1.29	0.57	0.26	1.27
120 to 124			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	833	11	1.56	0.84	2.90	1.54	0.83	2.87
60 to 69	25,933	233	1.05	0.91	1.21	1.05	0.91	1.21
70 to 79 (ref)	*135,868*	*1,258*	*1.00*			*1.00*		
80 to 89	133,431	1,237	0.96	0.89	1.04	0.95	0.88	1.03
90 to 120	2,911	34	1.20	0.85	1.70	1.14	0.81	1.61
125 to 129			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	321	3	n/a	n/a	n/a	n/a	n/a	n/a
60 to 69	8,614	95	1.19	0.97	1.47	1.18	0.96	1.46
70 to 79	59,059	651	1.09	0.99	1.21	1.07	0.97	1.18
80 to 89	76,312	934	1.15	1.05	1.25	1.11	1.02	1.21
90 to 120	3,665	46	1.24	0.92	1.67	1.17	0.86	1.58
130 to 139			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	238	2	n/a	n/a	n/a	n/a	n/a	n/a
60 to 69	5,222	106	1.78	1.45	2.18	1.65	1.35	2.03
70 to 79	46,301	751	1.33	1.21	1.46	1.26	1.15	1.39
80 to 89	122,103	2,172	1.42	1.32	1.52	1.33	1.24	1.43
90 to 120	15,318	291	1.61	1.41	1.84	1.47	1.28	1.68
140 to 149			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	598	24	3.02	1.98	4.61	2.55	1.67	3.89
70 to 79	4,113	99	1.64	1.33	2.03	1.47	1.19	1.82
80 to 89	17,914	480	1.75	1.57	1.95	1.54	1.38	1.71
90 to 120	14,206	339	1.77	1.56	2.00	1.54	1.36	1.74
150 to 159			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	121	2	n/a	n/a	n/a	n/a	n/a	n/a
70 to 79	622	32	3.50	2.44	5.03	2.95	2.06	4.25
80 to 89	2,831	127	2.42	2.00	2.93	2.05	1.69	2.48
90 to 120	5,846	201	2.25	1.93	2.62	1.86	1.60	2.17
160 to 199			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	106	4	n/a	n/a	n/a	n/a	n/a	n/a
70 to 79	321	11	2.27	1.22	4.23	1.93	1.04	3.60
80 to 89	1,045	52	2.75	2.07	3.66	2.18	1.64	2.91
90 to 120	3,981	208	3.04	2.62	3.54	2.31	1.98	2.69

n/a = Number of deaths <5

Table 4. Relative Mortality by BP for Females, Age 60 to 89, Accounting for Age and Smoking With and Without Additional Covariates

Systolic BP	Vital status		Covar=age+smoker			Covar=additional		
90 to 119			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	955	60	1.18	0.88	1.57	1.12	0.84	1.50
60 to 69	8,572	386	0.96	0.82	1.12	0.92	0.79	1.08
70 to 79	10,280	464	1.03	0.88	1.19	1.03	0.88	1.19
80 to 89	1,818	93	1.08	0.84	1.38	1.09	0.85	1.39
90 to 120	14	0	n/a	n/a	n/a	n/a	n/a	n/a
120 to 124			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	97	11	1.67	0.92	3.06	1.56	0.85	2.85
60 to 69	2,015	124	1.16	0.93	1.44	1.13	0.91	1.41
70 to 79 (ref)	*6,563*	*301*	*1.00*			*1.00*		
80 to 89	3,979	182	1.01	0.84	1.23	1.01	0.83	1.22
90 to 120	31	1	n/a	n/a	n/a	n/a	n/a	n/a
125 to 129			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	54	8	1.71	0.81	3.62	1.45	0.68	3.07
60 to 69	1,008	78	1.36	1.06	1.76	1.35	1.05	1.75
70 to 79	4,241	230	1.06	0.89	1.27	1.05	0.87	1.25
80 to 89	3,004	170	1.25	1.03	1.53	1.18	0.97	1.44
90 to 120	67	3	n/a	n/a	n/a	n/a	n/a	n/a
130 to 139			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	78	9	1.58	0.82	3.08	1.40	0.72	2.71
60 to 69	1,177	141	1.60	1.30	1.97	1.57	1.27	1.93
70 to 79	5,363	419	1.39	1.19	1.62	1.33	1.14	1.55
80 to 89	7,307	542	1.38	1.19	1.60	1.30	1.12	1.51
90 to 120	401	34	1.80	1.26	2.57	1.69	1.18	2.41
140 to 149			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	283	54	2.18	1.62	2.93	1.99	1.48	2.68
70 to 79	1,190	123	1.56	1.26	1.94	1.46	1.17	1.81
80 to 89	2,332	210	1.48	1.23	1.78	1.34	1.11	1.61
90 to 120	638	59	1.69	1.26	2.27	1.51	1.12	2.02
150 to 159			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	76	13	1.61	0.90	2.87	1.45	0.81	2.59
70 to 79	319	50	1.99	1.47	2.70	1.77	1.31	2.40
80 to 89	733	81	1.71	1.32	2.21	1.45	1.12	1.87
90 to 120	423	53	2.12	1.57	2.87	1.90	1.41	2.58
160 to 199			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	40	8	1.95	0.92	4.14	1.49	0.70	3.16
70 to 79	157	33	2.52	1.75	3.63	2.19	1.52	3.16
80 to 89	427	72	1.80	1.36	2.39	1.63	1.23	2.15
90 to 120	472	61	2.02	1.52	2.69	1.71	1.29	2.28

n/a = Number of deaths <5

Table 5. Relative Mortality by BP for Males, Age 60 To 89, Accounting for Age and Smoking With and Without Additional Covariates

Systolic BP	Vital status		Covar=age+smoker			Covar=additional		
90 to 119			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	743	90	1.50	1.20	1.88	1.39	1.11	1.74
60 to 69	7,962	582	1.09	0.97	1.22	1.08	0.96	1.21
70 to 79	13,448	762	0.94	0.84	1.05	0.95	0.85	1.06
80 to 89	2,901	159	0.99	0.83	1.18	0.98	0.83	1.17
90 to 120	38	1	n/a	n/a	n/a	n/a	n/a	n/a
120 to 124			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	117	15	1.33	0.80	2.22	1.24	0.74	2.07
60 to 69	2,532	227	1.21	1.03	1.41	1.19	1.02	1.38
70 to 79 (ref)	*10,044*	*619*	*1.00*			*1.00*		
80 to 89	7,172	413	0.94	0.83	1.07	0.94	0.83	1.07
90 to 120	94	7	1.12	0.53	2.35	1.04	0.49	2.19
125 to 129			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	59	6	1.25	0.56	2.80	1.12	0.50	2.50
60 to 69	1,318	134	1.28	1.06	1.55	1.24	1.03	1.51
70 to 79	6,895	439	0.98	0.86	1.11	0.97	0.85	1.09
80 to 89	5,994	373	1.03	0.90	1.17	1.01	0.88	1.15
90 to 120	133	10	1.22	0.63	2.35	1.09	0.57	2.11
130 to 139			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 59	72	19	2.71	1.71	4.27	2.22	1.41	3.51
60 to 69	1,570	217	1.49	1.27	1.74	1.39	1.19	1.63
70 to 79	9,282	847	1.23	1.11	1.37	1.19	1.07	1.33
80 to 89	14,913	1,201	1.19	1.08	1.31	1.14	1.03	1.25
90 to 120	905	66	1.12	0.86	1.46	1.04	0.80	1.35
140 to 149			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	298	62	1.91	1.47	2.49	1.58	1.22	2.06
70 to 79	1,809	219	1.41	1.20	1.65	1.26	1.07	1.47
80 to 89	4,468	462	1.34	1.19	1.52	1.26	1.11	1.43
90 to 120	1,445	139	1.39	1.15	1.67	1.24	1.03	1.50
150 to 159			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	74	20	2.04	1.28	3.26	1.61	1.01	2.58
70 to 79	404	76	1.75	1.38	2.23	1.49	1.17	1.90
80 to 89	1,253	162	1.47	1.23	1.76	1.33	1.11	1.59
90 to 120	929	114	1.64	1.34	2.03	1.44	1.17	1.77
160 to 199			**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic BP	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 69	41	19	3.39	2.15	5.36	2.88	1.82	4.55
70 to 79	191	34	1.50	1.05	2.13	1.22	0.86	1.73
80 to 89	616	97	1.60	1.28	2.01	1.35	1.08	1.69
90 to 120	912	130	1.72	1.42	2.10	1.43	1.17	1.74

n/a = Number of deaths <5

Table 6. Relative Mortality for Those Denying and Admitting to Hypertension

Systolic BP	Denies HTN		Admits HTN		Denies HTN			Admits HTN		
90-119	**Vital status**		**Vital status**		**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic	**alive**	**dead**	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 89	892,278	3,935	49,502	936	0.92	0.87	0.96	1.35	1.25	1.45
90 to 120	1,068	4	164	0	n/a	n/a	n/a	n/a	n/a	n/a
120-129					**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic	**alive**	**dead**	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 89	399,435	3,151	66,557	1,424	*1.00**			1.23	1.16	1.31
90 to 120	4,581	29	1,306	28	0.97	0.67	1.39	1.82	1.25	2.64
130-139					**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic	**alive**	**dead**	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 89	130,379	1,942	44,967	1,408	1.23	1.16	1.30	1.38	1.29	1.47
90 to 120	9,645	115	4,032	78	1.40	1.16	1.69	1.45	1.16	1.81
140-149					**MR**	**95% CI**		**MR**	**95% CI**	
Diastolic	**alive**	**dead**	**alive**	**dead**	**(Cox)**	**Lower**	**Upper**	**(Cox)**	**Lower**	**Upper**
50 to 89	20,499	607	13,491	731	1.52	1.39	1.66	1.58	1.45	1.72
90 to 120	14,217	294	8,919	299	1.52	1.34	1.71	1.60	1.42	1.80

* reference band is those denying hypertension history with BP 120-129/50-89

The lowest risk groups across all age and sex were those with SBP 90 to 119 (extending to SBP 80 for females age 18 to 59) consistent with many other studies showing a continuous relationship of SBP and risk with the lowest band having the lowest risk. Comparing SBP 90-119 to SBP 125-129, relative mortality increased by 13% to 32% depending on age and sex.

Within each SBP band, those with DBP ranging from 60 to 89 had similar risk which was often much lower than that for DBP 50 to 59 but only slightly lower than that for DBP 90 to 120. Very low diastolic values appeared to have higher risk related to increased pulse pressure presumably caused by a very stiff vasculature. However, rather than risk increasing progressively as pulse pressure increased, it increased only if the pulse pressure exceeded approximately ½ of SBP (1% of applicants) as shown in Figure 1. This finding is consistent with data from Domanski et al (cardiovascular deaths) using the MRFIT data set and from Franklin et al (cardiovascular events) using Framingham data.[8,9] The more limited numbers in those studies did not allow the divisions possible for our study, which more clearly shows the relatively sharp threshold at >½ SBP across age and SBP. Those two studies and Sesso et al, using Physicians Health Study data, also only examined pulse pressure as an absolute value.[10] Increasing risk is also apparent for pulse pressure >½ SBP in the 2003 Swiss Re study (all-cause mortality and insured lives) but only for SBP >140.[2] We were unable to find prior studies analyzing pulse pressure as a percent of SBP rather than as an absolute value.

Our finding of an increased risk for all-cause mortality associated with a hypertension history when BP is controlled (Table 6) is at odds with that of Barengo et al in a 2013 Finnish population study (which also used BP of 140/90 as the discriminator for BP control and used an adjusted analysis).[5] However, cardiovascular mortality in their hypertensive history group was increased to 1.18, meaning non-cardiovascular relative mortality (not discussed in that article) for treated and controlled hypertension must have been substantially reduced for unknown reasons. That paper also reviewed prior literature (all of which was over 10 years old and much of which

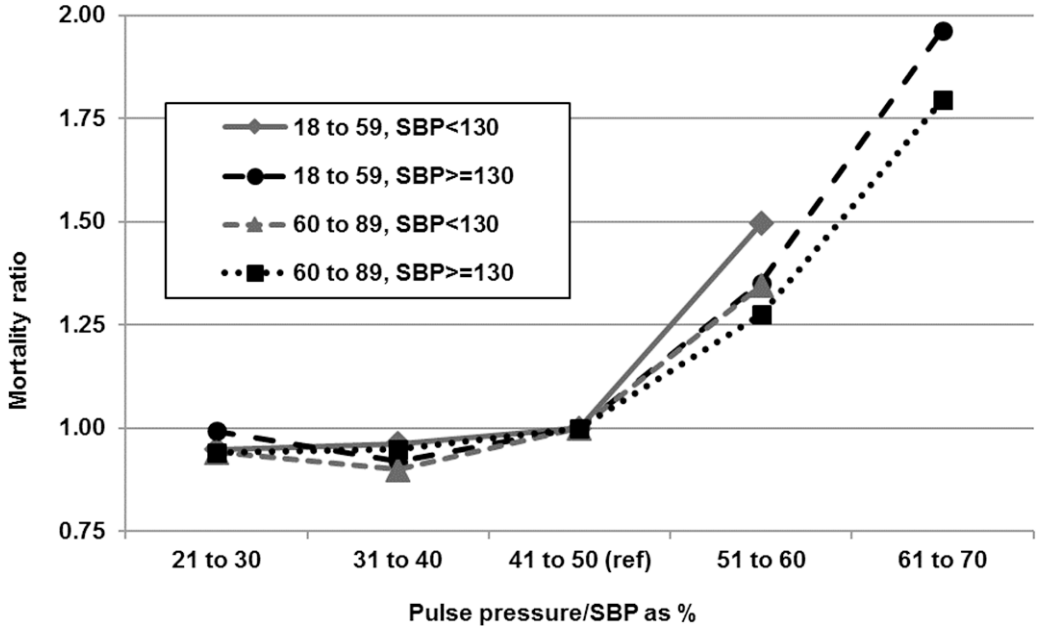

Figure. *Relative Mortality for Pulse Pressure/SBP, by Age and SBP Group.*

uses a higher BP cut-off value to define control), and found inconsistent answers on this question. Our results, showing increased risk associated with hypertension history, are based on far larger numbers but use a more selected (insurance applicant) population.

Limitations for our study include dependence on 1 to 3 BP measurements (just 1 for 24% of applicants) done at a single exam by paramedical examiners whose business is, in part, dependent on insurance agent/broker satisfaction, a relationship which might be associated with downward rounding. In addition, our historical information was limited to the questions on the laboratory authorization (answer encouraged but usually not required) rather than on the insurance application. Our study population of individual life insurance applicants also has fewer serious medical conditions and a higher socio-economic status as compared to a general population sample.

CONCLUSION

Systolic blood pressure was associated with substantial increases in relative mortality across age and sex in continuous manner from SBP <120 upward to SBP 160+ with little contribution to risk assessment by DBP. Adjustment for the impact of BMI, proteinuria and heart disease history attenuated that increase modestly. In addition, pulse pressure exceeding ½ SBP had substantial increased mortality.

Hypertension history with current BP control was associated with increased risk relative to those with comparable SBP but without such history.

REFERENCES

1. *Blood Pressure Study, 1979*. Society of Actuaries and Association of Life Insurance Medical Directors of America. Chicago, IL. 1980.
2. Pinkham CA, Ivanovic B, Cumming ME. 2003 Swiss Re blood pressure study of insured lives. *No. Am. Actuarial J*. 2005;9:1–16.
3. Barengo NC, Antikainen R, Kastarinen M, et al. The effects of control of systolic and diastolic hypertension and all-cause mortality in a community-based population cohort. *J Hum Hypertens*. 2013;27:693–697.
4. Fulks M, Stout RL, Dolan VF. 2014 CRL build study. *J Insur. Med*. In press.
5. Fulks M, Stout RL, Dolan VF. Urine protein/creatinine ratio as a mortality risk predictor in non-diabetics with normal renal function. *J. Insur. Med*. 2012;43:76–83.

6. Wright JD, Hughes JP, Ostchega Y, et al. Mean systolic and diastolic blood pressure in adults aged 18 and over in the United States, 2001-2008. *Natl Health Stat Report*. 2011;25: 1-22, 24.
7. Centers for Disease Control and Prevention. Vital signs: prevalence, treatment and control of hypertension - United States, 1999-2002 and 2005-2008. *MMWR Morb Mortal Wkly Rep*. 2011; 60:103–108.
8. Domanski M, Mitchell G, Pfeffer M, et al. Pulse pressure and cardiovascular disease-related mortality. Follow-up study of the Multiple Risk Factor Intervention Trial (MRFIT). *JAMA*. 2002;287: 2677–2683.
9. Franklin SS, Lopez VA, Wong ND, et al. Single versus combined blood pressure components and risk for cardiovascular disease. The Framingham Heart Study. *Circulation*. 2009;119:243–250.
10. Sesso HD, Stampfer MJ, Rosner B, et al. Systolic and diastolic blood pressure, pulse pressure, and mean arterial pressure as predictors of cardiovascular disease risk in men. *Hypertension*. 2000;36:801–807.