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**MORTALITY**

# 2014 CRL Build Study of Life Insurance Applicants

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**Objective.—**Determine the impact of build on insurance applicant mortality accounting for smoking, laboratory test values and blood pressure.

**Method.—**The study consisted of 2,051,370 applicants tested at Clinical Reference Laboratory between 1993 and 2007 with build and cotinine measurements available whose body mass index (BMI) was between 15 and 47. Vital status was determined as of September, 2011 by the Social Security Death Master File. Excluded from the primary study were applicants with HbA1c values ≥6.5%, systolic BP ≥141 mmHg, albumin values ≤3.3 g/dL or total cholesterol values ≤130 mg/dL. Relative mortality was determined by Cox regression analysis for bands of BMI split by age, sex and smoking status (urine cotinine positive).

**Results.—**A majority of applicants had BMI >24 (overweight or obese by WHO criteria). After the exclusions noted above, relative mortality does not increase by >34% unless BMI is <20 (<18 for female non-smokers age 18 to 59) or BMI is >34. BMI values in the range of 22 to 24 and 25 to 29, overall, had similar and the lowest relative risks. For most nonsmokers, risk was lowest in the lower of these two BMI bands but for smokers (and non-smoking males age 60 to 89) risk was lowest in the higher BMI band.

Additional analysis showed limited reduction in relative risk by accounting for all laboratory test values as well as continuing the exclusions. Eliminating the exclusions resulted in only a modest increase in relative risk because the mortality rate of the reference band increased as well.

**Conclusion.—**After excluding elevated HbA1c and blood pressure (associated with high BMI) and low albumin and cholesterol (associated with low BMI) which are usually evaluated separately, mortality varies by a limited degree for BMI 20 to 34. Accounting for the mortality impact of other test values, in addition to the exclusions noted, reduced mortality associated with high BMI to a limited extent, but had little impact on mortality associated with low BMI.

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Build was one of the earliest objective measures used in the evaluation of risk for life insurance applicants (although underweight was originally a greater concern). Currently, almost all major studies of obesity or underweight use the body mass index (BMI), which is a convenient surrogate for the percentage of body fat and is calculated by: weight (lb)/ height$^2$ (in) x 703 or weight (kg)/ height$^2$ (m). It allows individuals of various heights to be considered together and serves as the basis for most recent height-weight tables.

BMI for residents of North America has been steadily increasing; although there is

evidence it is now at a plateau. BMI has increased to a median value of approximately 27 for both sexes and is 30 or higher for 1/3 of the adult population.[1] This has shifted many of the "healthy" lives to higher BMI and, as a result, recent mortality studies show no difference in risk between BMI values 22 to 24 and those in the 25 to 29 range ("overweight" by WHO criteria).[2,3] In addition to a flattening of the relative mortality curve, an increasing relative risk might be anticipated for low BMI values.

Higher BMI is linked to findings associated with excess mortality including chronically elevated blood sugar and increased blood pressure. Conditions potentially leading to lower BMI include smoking, chronic illness, eating disorders and alcohol abuse, possibly resulting in low cholesterol and/or albumin values as well. Published work on BMI often does not exclude individuals with test or blood pressure abnormalities but only with diagnosed diseases based on the stated rationale that those findings are often the mechanism by which high or low BMI influences mortality risk.[4-8] An exception to this is a Korean study, where laboratory results were included as covariates and found to have a substantial impact on the relationship between BMI and mortality.[9] The risk attributed to high or low BMI after accounting for laboratory findings (as is done during life insurance underwriting), therefore, may be lower than that suggested from most studies.

The available BMI mortality literature is mostly based on general adult populations such as NHANES, often with limited numbers of deaths, restricting the ability to generate mortality ratios for narrow BMI bands or those at very high or low values (eg, BMI 18 or 42). Because of that and the potential added benefit of adjusting for other test values consistent with the assessment of tested life insurance applicants (and patients having a wellness exam), we conducted a BMI mortality study on a large pool of insurance applicants for whom height, weight, blood pressure and laboratory test results were available.

## 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 results are sent to the insurer requesting the testing. Many tested applicants also have physical measurements performed including height, weight and blood pressure (BP) with results transmitted via the laboratory to the insurer.

We studied 2,051,370 insurance applicants (19,714 deaths) tested at CRL between 1993 and 2007 with height and weight measurements (few prior to 2001) and urine cotinine measurement available in addition to meeting the test value exclusions noted below. Follow-up for vital status was conducted using 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 7.0 years (range 0 to 18).

Applicants were excluded from the primary study if they had HbA1c values $\geq$6.5%, systolic BP $\geq$141 mmHg, albumin values $\leq$3.3 g/dL or total cholesterol values $\leq$130 mg/dL. This group comprised 15.7% of applicants tested between 1993 and 2007 with all laboratory and physical measurement data available, and was removed to avoid potentially inflating the high or low BMI risk ratios for findings already commonly considered separately for both clinical and insurance risk assessment. Also excluded were BMI values $<$15 or $>$47 (0.3% of those meeting other exclusion criteria) to more accurately represent the risk of our highest and lowest bands shown, as well as avoid the increased likelihood of data entry errors for height and weight.

Relative mortality risk was calculated by Cox regression analysis using IBM SPSS version 22. Analyses were split by smoker status (smoking defined as urine cotinine >200 ng/mL) and by age 18 to 59 and 60 to 89, with age also included as a covariate within these bands. For non-smokers, analyses were also split by sex while that was included only as a covariate for smokers due to more limited numbers and very similar mortality ratios by sex (data not shown). Bands of BMI values were chosen based on available data with BMI 22 to 24 as the reference because that was the band most often (but not always) associated with the lowest risk.

In a secondary analysis, an additional covariate was added consisting of a proprietary numeric score representing the age- and sex-specific mortality risk associated with all laboratory test values and BP combined (but excluding BMI).[10] Resulting total scores <0 (favorable) were set to 0 as we wished to account only for adverse findings from other tests. The same exclusions were used as noted above. Whereas the primary analysis establishes the "screening risk" of BMI in those with exclusions, this secondary analysis provides a rough estimate of what risk remains for various BMI values if any additional risk from all other laboratory results is fully accounted for in addition to the exclusions. Data was also analyzed without the exclusions or adjustments (not shown).

## RESULTS

Tables 1–4 include non-smokers (after exclusions noted in Methods) showing the distribution of BMI values, deaths and relative mortality split by sex and age 18 to 59 and 60 to 89. The mortality ratios are shown along with 95% confidence intervals when including only age as a covariate and when including both age and any adverse mortality scores for the other tests and BP. Tables 5 and 6 show similar information for smokers but with sex as a covariate rather than shown as a separate set of tables. For more extreme values of BMI, especially for smokers, deaths are limited and confidence intervals wider; consideration of the trend across BMI bands and to other age-sex-smoker groups may be helpful when evaluating the mortality ratios generated from groups with wide confidence intervals.

The majority of non-smokers studied had a BMI >24 (with the exception of females age <60 where 45% have a BMI >24) meaning that the majority of applicants were at least "overweight" by WHO criteria. For smokers (who were not split by sex but only by age), the majority of applicants in both age bands had a BMI >24.

Mortality for BMI <20 was substantially increased relative to BMI 22 to 24 except for female non-smokers age 18 to 59 where the increase in risk did not occur until BMI <18. Relative mortality of BMI 30 to 34 for non-smokers showed a 30% to 49% increase except for males age 60 to 89 with a smaller 8% increase. For smokers, this higher BMI band actually had a lower mortality relative to the reference band. Progressively higher and lower BMI beyond these bands had progressively higher relative risk for smokers and non-smokers.

The relative mortality risk after accounting for the adverse impact of other tests and BP (and after the exclusions noted in Methods) is also shown in Tables 1–6. Inclusion of that additional covariate resulted in progressively larger reductions in the relative risk associated with increasing BMI but had minimal impact on the risk associated with decreasing BMI.

Exclusion criteria removed 15.5% of lives and 32.8% of deaths from the potential applicant pool with smallest impact for younger females (9.2% and 20.8% respectively) and largest for older males (26.7% and 38.8%). Not using these exclusions (data not shown) increased the percentage of applicants in extreme BMI bands but, on average, resulted in only modestly higher mortality ratios for those bands because the reference mortality rate (dead/ dead + alive) increased as well. Relative risk within BMI 20 to 29 across age,

**Table 1.** Female Non-smokers Age 18 to 59

| BMI group | Vital status | | | Covar = age | | | Covar = age and other test-mortality score | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | MR | 95% CI | | MR | 95% CI | |
| | Alive | Dead | Distn | (Cox) | Lower | Upper | (Cox) | Lower | Upper |
| 15 to 17 | 12,876 | 45 | 1.6% | **1.55** | 1.14 | 2.09 | **1.61** | 1.19 | 2.18 |
| 18 to 19 | 71,089 | 192 | 8.8% | **1.06** | 0.90 | 1.25 | **1.13** | 0.96 | 1.32 |
| 20 to 21 | 143,417 | 383 | 17.8% | **0.93** | 0.82 | 1.06 | **0.98** | 0.86 | 1.11 |
| **22 to 24*** | 214,881 | 688 | 26.6% | **1.00** | | | **1.00** | | |
| 25 to 29 | 220,792 | 873 | 27.4% | **1.13** | 1.02 | 1.24 | **1.02** | 0.92 | 1.13 |
| 30 to 34 | 93,250 | 459 | 11.6% | **1.37** | 1.22 | 1.54 | **1.10** | 0.98 | 1.25 |
| 35 to 39 | 36,291 | 204 | 4.5% | **1.63** | 1.40 | 1.91 | **1.22** | 1.04 | 1.43 |
| 40 to 41 | 6551 | 52 | 0.8% | **2.34** | 1.76 | 3.10 | **1.69** | 1.27 | 2.24 |
| 42 to 47 | 7743 | 71 | 1.0% | **2.87** | 2.25 | 3.67 | **1.96** | 1.53 | 2.50 |
| Total | 806,890 | 2967 | | | | | | | |

*(* reference group BMI 22 to 24)*

sex and smoking status was almost identical with or without exclusions.

## DISCUSSION

Our relative mortality findings are consistent with other recent studies although because of our comparatively large study population we were able to split by age, sex, smoking and additional BMI bands for extreme values not consistently available from prior studies. One new finding was the stable relative mortality for non-smoking women age <60 down to a BMI of 18. The separate analysis for smokers and non-smokers also allowed for more precise mortality ratios for each group across a wide range of BMI. Smokers had less relative risk at greater BMI and more risk at lower BMI as compared to non-smokers, consistent with the more limited data for the NIH-AARP study.[7]

When more extreme high values of HbA1c and systolic BP and more extreme low values of albumin and cholesterol were excluded

**Table 2.** Male Non-smokers Age 18 to 59

| BMI group | Vital status | | | Covar = age | | | Covar = age and other test-mortality score | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | MR | 95% CI | | MR | 95% CI | |
| | Alive | Dead | Distn | (Cox) | Lower | Upper | (Cox) | Lower | Upper |
| 15 to 17 | 2179 | 14 | 0.2% | **1.52** | 0.90 | 2.57 | **1.44** | 0.85 | 2.43 |
| 18 to 19 | 11,792 | 73 | 1.3% | **1.44** | 1.13 | 1.82 | **1.42** | 1.12 | 1.79 |
| 20 to 21 | 45,088 | 226 | 5.1% | **1.06** | 0.92 | 1.22 | **1.06** | 0.92 | 1.23 |
| **22 to 24*** | 201,380 | 1081 | 23.0% | **1.00** | | | **1.00** | | |
| 25 to 29 | 430,677 | 2773 | 49.2% | **1.11** | 1.03 | 1.19 | **1.07** | 0.99 | 1.14 |
| 30 to 34 | 141,585 | 1251 | 16.2% | **1.49** | 1.37 | 1.62 | **1.34** | 1.24 | 1.46 |
| 35 to 39 | 32,993 | 333 | 3.8% | **1.77** | 1.57 | 2.00 | **1.47** | 1.30 | 1.66 |
| 40 to 41 | 4486 | 59 | 0.5% | **2.44** | 1.88 | 3.17 | **1.85** | 1.42 | 2.41 |
| 42 to 47 | 4127 | 70 | 0.5% | **3.29** | 2.58 | 4.19 | **2.41** | 1.89 | 3.08 |
| Total | 874307 | 5880 | | | | | | | |

*(* reference group BMI 22 to 24)*

**Table 3.** Female Non-smokers Age 60 to 89

| BMI group | Vital status | | | Covar = age | | | Covar = age and other test-mortality score | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | MR | 95% CI | | MR | 95% CI | |
| | Alive | Dead | Distn | (Cox) | Lower | Upper | (Cox) | Lower | Upper |
| 15 to 17 | 432 | 61 | 1.0% | **2.36** | 1.81 | 3.09 | **2.33** | 1.79 | 3.05 |
| 18 to 19 | 2082 | 160 | 4.6% | **1.53** | 1.28 | 1.83 | **1.51** | 1.26 | 1.81 |
| 20 to 21 | 5274 | 277 | 11.4% | **1.17** | 1.01 | 1.35 | **1.19** | 1.03 | 1.38 |
| **22 to 24*** | 11,661 | 478 | 24.9% | **1.00** | | | **1.00** | | |
| 25 to 29 | 16,754 | 700 | 35.8% | **1.11** | 0.99 | 1.25 | **1.08** | 0.96 | 1.21 |
| 30 to 34 | 7220 | 316 | 15.5% | **1.30** | 1.13 | 1.50 | **1.18** | 1.02 | 1.36 |
| 35 to 39 | 2362 | 129 | 5.1% | **1.79** | 1.47 | 2.18 | **1.55** | 1.28 | 1.89 |
| 40 to 41 | 365 | 22 | 0.8% | **2.07** | 1.35 | 3.17 | **1.72** | 1.12 | 2.65 |
| 42 to 47 | 375 | 21 | 0.8% | **2.14** | 1.38 | 3.32 | **1.66** | 1.07 | 2.58 |
| Total | 46,525 | 2164 | | | | | | | |

*(* reference group BMI 22 to 24)*

and the adverse risk of other test values was included as a covariate, the risk for any BMI ranging from 20 to 34 for non-smokers relative to the reference BMI 22 to 24 varied a maximum of 34% (and usually far less). For smokers, that risk variation was less. The relative risk associated with BMI <20 (<18 for younger females) or >34 showed steady increases even after the exclusions and adjustments. Adding an adjustment for other test results in addition to the exclusions reduced relative risk progressively and substantially as BMI increases, but has little impact on low BMI where history of stable weight and activity level (which we did not have) or history of illness might provide more guidance in determining the risk for an individual.

Exclusions for high HbA1c, high BP, low cholesterol and low albumin had a surprisingly limited impact on distribution and relative risk (data not shown). Instead, the mortality rate for all BMI bands including the reference band was increased when the exclusions were removed. This is a reminder that these adverse findings are actually distributed across a full range of BMI and are

**Table 4.** Male Non-smokers Age 60 to 89

| BMI group | Vital status | | | Covar = age | | | Covar = age and other test-mortality score | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | MR | 95% CI | | MR | 95% CI | |
| | Alive | Dead | Distn | (Cox) | Lower | Upper | (Cox) | Lower | Upper |
| 15 to 17 | 125 | 25 | 0.2% | **2.37** | 1.59 | 3.52 | **2.16** | 1.45 | 3.21 |
| 18 to 19 | 500 | 50 | 0.8% | **1.29** | 0.97 | 1.71 | **1.22** | 0.92 | 1.62 |
| 20 to 21 | 2364 | 200 | 3.7% | **1.20** | 1.03 | 1.40 | **1.13** | 0.97 | 1.32 |
| **22 to 24*** | 13,184 | 863 | 20.3% | **1.00** | | | **1.00** | | |
| 25 to 29 | 34,245 | 1767 | 52.1% | **0.92** | 0.85 | 1.00 | **0.91** | 0.84 | 0.99 |
| 30 to 34 | 12,011 | 648 | 18.3% | **1.08** | 0.97 | 1.19 | **1.04** | 0.94 | 1.16 |
| 35 to 39 | 2423 | 142 | 3.7% | **1.25** | 1.04 | 1.49 | **1.16** | 0.97 | 1.38 |
| 40 to 41 | 275 | 25 | 0.4% | **1.98** | 1.33 | 2.95 | **1.76** | 1.18 | 2.63 |
| 42 to 47 | 214 | 17 | 0.3% | **1.76** | 1.09 | 2.85 | **1.49** | 0.92 | 2.41 |
| Total | 65,341 | 3737 | | | | | | | |

*(* reference group BMI 22 to 24)*

**Table 5.** Smokers Age 18 to 59

| BMI group | Vital status | | | Covar = age and sex | | | Covar = age, sex and other test-mortality score | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | MR | 95% CI | | MR | 95% CI | |
| | Alive | Dead | Distn | (Cox) | Lower | Upper | (Cox) | Lower | Upper |
| 15 to 17 | 2649 | 61 | 1.2% | **1.85** | 1.43 | 2.40 | **1.70** | 1.31 | 2.20 |
| 18 to 19 | 11,299 | 213 | 4.9% | **1.43** | 1.23 | 1.66 | **1.42** | 1.23 | 1.65 |
| 20 to 21 | 24,774 | 389 | 10.8% | **1.05** | 0.93 | 1.18 | **1.06** | 0.94 | 1.19 |
| **22 to 24*** | 54,540 | 936 | 23.8% | **1.00** | | | **1.00** | | |
| 25 to 29 | 89,425 | 1382 | 39.0% | **0.83** | 0.77 | 0.91 | **0.82** | 0.75 | 0.89 |
| 30 to 34 | 34,026 | 532 | 14.8% | **0.91** | 0.82 | 1.02 | **0.85** | 0.77 | 0.95 |
| 35 to 39 | 9626 | 155 | 4.2% | **1.08** | 0.91 | 1.28 | **0.93** | 0.79 | 1.10 |
| 40 to 41 | 1336 | 26 | 0.6% | **1.46** | 0.99 | 2.16 | **1.21** | 0.82 | 1.79 |
| 42 to 47 | 1415 | 29 | 0.6% | **1.60** | 1.10 | 2.31 | **1.34** | 0.93 | 1.94 |
| Total | 229,090 | 3723 | | | | | | | |

*(* reference group BMI 22 to 24)*

only somewhat more prevalent at more extreme BMI values.

We used BMI 22 to 24 as the reference (as have most studies). However, more insurance applicants actually have a BMI in the 25 to 29 range and mortality between the two bands is similar with lower risk actually being in the higher band for older male non-smokers and all smokers. This is true without exclusions as well (data not shown). The entire BMI 22 to 29 band may be a more practical reference group when defining what is currently "normal" across age, sex and smoking status for mortality risk assessment purposes.

As Americans have broadened, the BMI band with the lowest relative risk has also broadened and moved higher, leaving lower BMI bands with a lower percentage of healthy lives and higher relative risk. However, this population trend to higher BMI is likely to be associated with a higher overall mortality rate (in contrast to relative risk between BMI bands) which cannot be discerned from studies with a design similar to ours. Increasing

**Table 6.** Smokers Age 60 to 89

| BMI group | Vital status | | | Covar = age and sex | | | Covar = age, sex and other test-mortality score | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | MR | 95% CI | | MR | 95% CI | |
| | Alive | Dead | Distn | (Cox) | Lower | Upper | (Cox) | Lower | Upper |
| 15 to 17 | 151 | 50 | 1.9% | **2.32** | 1.72 | 3.14 | **2.05** | 1.52 | 2.77 |
| 18 to 19 | 448 | 99 | 5.1% | **1.54** | 1.23 | 1.94 | **1.52** | 1.21 | 1.91 |
| 20 to 21 | 933 | 153 | 10.1% | **1.19** | 0.98 | 1.44 | **1.16** | 0.96 | 1.41 |
| **22 to 24*** | 2320 | 308 | 24.5% | **1.00** | | | **1.00** | | |
| 25 to 29 | 3921 | 439 | 40.6% | **0.87** | 0.75 | 1.01 | **0.89** | 0.76 | 1.02 |
| 30 to 34 | 1413 | 150 | 14.5% | **0.88** | 0.72 | 1.07 | **0.88** | 0.73 | 1.07 |
| 35 to 39 | 251 | 33 | 2.6% | **1.06** | 0.74 | 1.52 | **1.05** | 0.73 | 1.51 |
| 40 to 41 | 34 | 6 | 0.4% | **1.71** | 0.76 | 3.84 | **1.46** | 0.65 | 3.29 |
| 42 to 47 | 32 | 5 | 0.3% | **1.52** | 0.63 | 3.68 | **1.36** | 0.56 | 3.29 |
| Total | 9503 | 1243 | | | | | | | |

*(* reference group BMI 22 to 24)*

disability may also begin at BMI 25 to 29 even after adjustment for other conditions.[3]

The possibility of using waist circumference (increased by abdominal rather than gluteofemoral obesity) in addition to BMI is suggested by Cerhan et al based on a recent study of pooled data including a mix of measured and reported measurements as well as the earlier EPIC study.[11,12] Using waist circumference ranges of 36 to 44 inches for males and 28 to 36 inches for females, Cerhan et al showed additional risk discrimination (50% increased risk for largest waist sizes) associated with the wide BMI range we found to be at low to modest extra risk in our study. If such measurements could be accurately obtained (a big "if"), they might add additional risk discrimination across a range of BMI encompassing most insurance applicants.

Limitations for our study include lack of history regarding BMI stability, exercise or diet (especially for low BMI). Due to the limited numbers of smokers, the data required adjusting for, rather than splitting by sex, although preliminary analysis using such a split showed similar mortality ratios. For some more extreme BMI bands, 95% confidence intervals are wide. In addition, no information on ethnicity is collected during the application process, and some differences in mortality by race may be present within various BMI bands.[5,8]

## CONCLUSION

A majority of tested insurance applicants had a BMI >24 and would be considered overweight or obese by WHO criteria. After excluding applicants with very low albumin or cholesterol, and very high HbA1c or BP values, relative mortality does not increase substantially unless BMI is <20 (<18 for female non-smokers age 18 to 59) or unless BMI is >34. BMI values in the range of 22 to 24 and 25 to 29, overall, had similar and lowest relative risks.

Accounting for the mortality impact of other adverse test values, in addition to using the exclusions noted, reduced mortality associated with high BMI to a limited extent, but that adjustment had little impact on mortality associated with low BMI. Not using the exclusions or adjustments increased relative risk only for BMI <20 or >29 and only modestly because the reference band mortality rate increased as well.

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