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Quantifying Wellbeing: What are the Keys to a Longer Life?

Novel findings on traditional and non-traditional risk factors from the RGA-sponsored UK Biobank mortality study with the University of Leicester

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Introduction

Supported by a large body of published research, insurers have long understood the significance of features such as body mass index (BMI), blood pressure, and serum cholesterol as predictive risk factors for poor health outcomes.[1-5] However, while these metrics are well-established indicators of health risks in the general population, insurers have often lacked the ability to accurately quantify the associations between these variables and the risk of mortality and morbidity events in insured lives. Bridging this gap is critical and can offer multiple benefits to both applicants and insurers.

For insurers, enhancing risk assessment can improve underwriting strategies, ultimately leading to optimized pricing. For applicants, a greater understanding of how factors such as exercise, influence their health could encourage behavior changes and strengthen engagement with insurance-related wellness programs, positioning insurers as partners in their pursuit of a healthy lifestyle.

While traditional risk factors such as BMI have been used universally for decades in underwriting, non-traditional risk factors such as walking pace and objective measures of physical activity remain relatively new and have yet to be fully integrated into underwriting practices. For example, despite RGA identifying step counts as a meaningful predictor of mortality several years ago,[6] most underwriting manuals have refrained from incorporating this metric due to a lack of relevant data in insurable lives.

In this paper, we share some valuable insights from our UK Biobank study with the University of Leicester into how traditional (e.g., BMI) and non-traditional (e.g., wearable-measured step counts) risk factors impact mortality.[7-8] Since 2022, RGA has been sponsoring and collaborating with world-renowned academics from the University of Leicester to develop valuable research insights from the UK Biobank database to help strengthen the understanding of biometric data for disease and death prognostication.[7-9] Interestingly, due to a "healthy volunteer" selection bias,[10] the UK Biobank is naturally more representative of standard insured lives in comparison to the general population, making these unique insights

Important Note: the UK Biobank data were only provided to the academic research team at the University of Leicester. RGA does not have access to any of the data. UK Biobank Project ID: 83825

particularly relevant to the insurance industry. We took it one step further by ensuring the risk models in our analysis were also:

a) **Stratified** by a proxy for underwriting class (e.g., standard, rated, and chronic disease lives)

b) **Split** by age and sex groups (where possible)

c) **Controlled** for typical underwriting risk factors (e.g., BMI, smoker status, systolic blood pressure, total cholesterol, socioeconomic status, and a prevalent history of cancer, cardiovascular disease, and diabetes)

d) **Statistically robust** (via leveraging a dataset of more than 500,000 participants who make up the core UK Biobank population)

Here, we segmented the UK Biobank database into the different cohorts before applying advanced statistical techniques to:

a) **Illustrate** the relationships between BMI, self-reported walking pace, and wearable-measured step counts and all-cause mortality

b) **Evaluate** the predictive power of replacing each traditional underwriting risk factor in the base model (i.e., BMI, smoker status, systolic blood pressure, and total cholesterol) with self-reported walking pace and wearable-measured step counts

Finally, we examine the broader implications of this research and explore its potential value for insurers.

Findings

BMI: New insights into an old rating factor

Figure 1 below illustrates the strong "U-shaped" relationship between BMI and mortality risk in UK Biobank male participants under 60, after controlling for traditional underwriting risk factors. An individual with a BMI of 17.5 kg/m^2 was found to have three times the mortality risk compared to a peer with a BMI of 27 kg/m^2 (median BMI value in this age and gender group). Similarly, at the other end of the spectrum, the mortality risk in an individual with a BMI of 50 kg/m^2 also had an approximately three times higher mortality risk compared to the median. This significant association was largely consistent across all data subsets (i.e., all age and sex groups as well as proxy for standard, rated, and chronic disease lives; data not shown).

Figure 1
Body mass index vs. all-cause mortality in all UK Biobank male lives aged <60 years

The most striking result is the high mortality impact at low BMI values, particularly those in the range of 17.5 to 20 kg/m^2. Not surprisingly, such findings have been underreported because previous medical studies have been focused on different populations or have employed different modeling strategies. For instance, in relation to the latter, many have not fully controlled for underwriting-relevant risk factors or failed to appropriately address non-linearity in the data (e.g., categorized the data or not allowed for sufficient flexibility via optimizing the number and positions of knots that define the spline terms).

For example, Bhaskaran et al. conducted a population-level analysis of 3.6 million UK adults to investigate the impact of BMI on overall and cause-specific mortality.[1] They observed a "J-Shaped" relationship with a mortality ratio of around 2 at low BMI values. Similar findings were also presented in two large meta-analyses.[2-3] More recently, Rigatti and Stout quantified the mortality effect of low BMI in life insurance applicants.[11] However, they also reported smaller hazard ratios than those observed in the UK Biobank data.

Further research is needed to better understand the significance of these findings and their implications for underwriting individuals with low BMI. In particular, Sun et al. showed that an increased risk of mortality for being underweight was only evident in ever smokers in the UK Biobank as well as the HUNT study.[12]

Walking pace: A strong self-reported predictor of all-cause mortality

Figure 2 shows the compelling association between self-reported walking pace and mortality risk in all UK Biobank male participants under 60, after controlling for traditional underwriting risk factors. Compared to individuals who typically walk at a slow pace, those with a steady average walking pace had a 40% lower mortality risk, while those who usually walk briskly had a 50% lower risk. This robust relationship remained consistent across all data subsets (i.e., all age and sex groups as well as proxy for standard, rated, and chronic disease lives; data not shown).

Walking pace definitions

- **Slow pace** = less than 3 miles per hour
- **Steady average pace** = between 3-4 miles per hour
- **Brisk pace** = more than 4 miles per hour

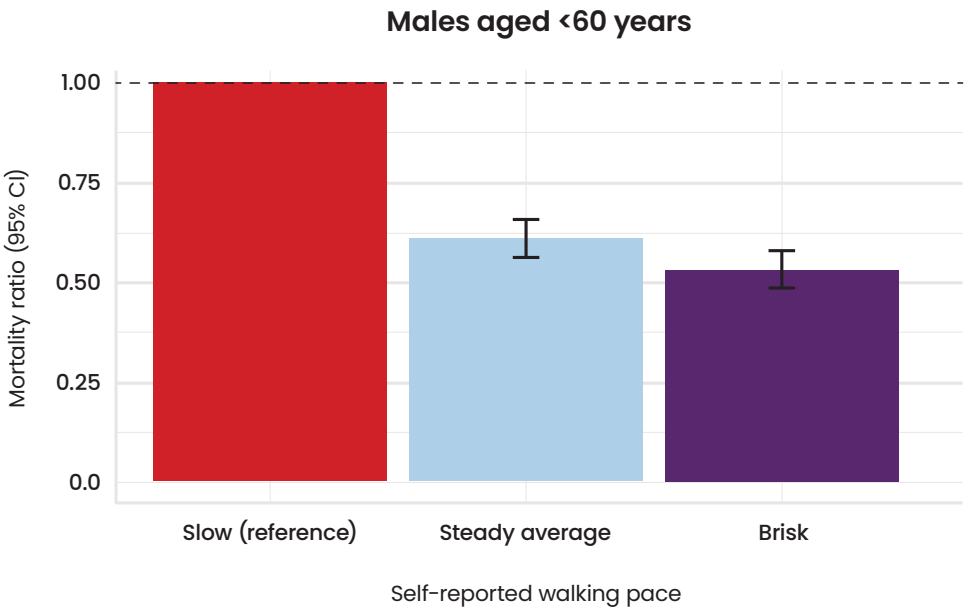

Figure 2
Self-reported walking pace vs. all-cause mortality in all UK Biobank male lives aged <60 years

Although this association has previously been reported in the literature,[13-14] it is remarkable to see it sustained in our various subsets of insurable lives. Moreover, incorporating self-reported walking pace into the base model for UK Biobank male participants under 60 increased the model's predictive power for mortality risk by ~2%, demonstrating the additional value this metric provides beyond traditional underwriting risk factors. Again, this

finding was largely consistent across data subsets (i.e., all age and sex groups, as well as proxy for standard, rated, and chronic disease lives; data not shown).

Figure 3 below shows the predictive power of replacing each traditional underwriting risk factor in the base model (i.e., BMI, smoker status, systolic blood pressure, and total cholesterol) with self-reported walking pace in all UK Biobank male participants under 60.

For example, the model's ability to predict mortality risk increased slightly when systolic blood pressure was replaced with self-reported walking pace. A similar effect was observed for total cholesterol, suggesting that self-reported walking pace is a marginally stronger predictor of mortality than systolic blood pressure and total cholesterol in the UK Biobank cohort. However, model accuracy declined when BMI and smoker status were independently replaced with self-reported walking pace – emphasizing the importance of these traditional underwriting risk factors in the UK Biobank cohort. These findings were generally consistent across different data subsets (i.e., all age and gender groups, as well as proxy for standard, rated, and chronic disease lives; data not shown).

It is important to note that walking pace data in the UK Biobank were self-reported – not objectively measured. As a result, these results should be interpreted with caution.

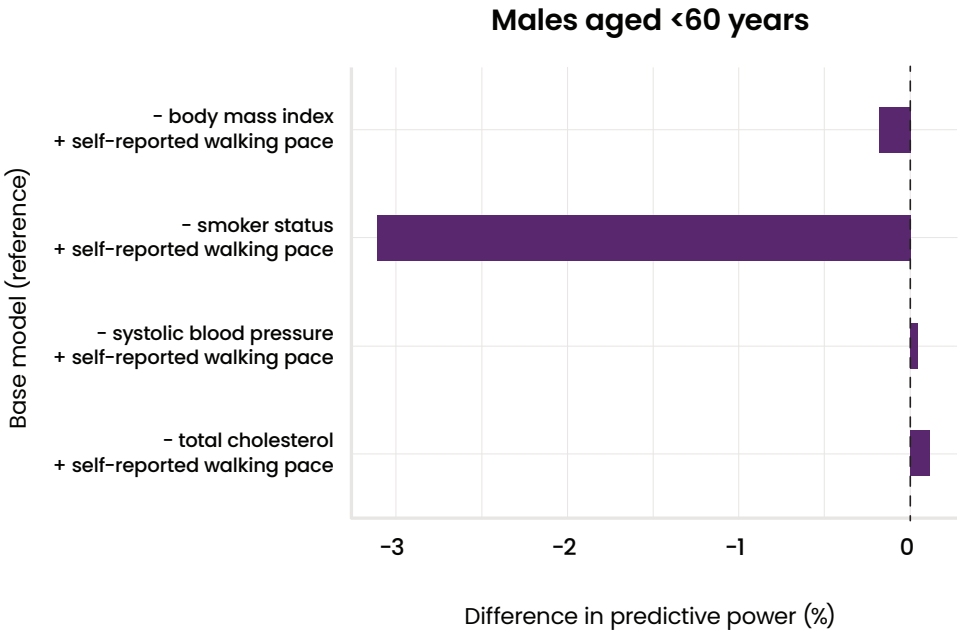

Figure 3
Quantifying the predictive power of individually replacing each traditional underwriting risk factor in the base model (i.e., body mass index, smoker status, systolic blood pressure, and total cholesterol) with self-reported walking pace in all UK Biobank male lives aged <60 years

Step counts: A strong wearable-measured predictor of all-cause mortality

Figure 4 illustrates the predominantly negative linear relationship between wearable-measured step counts and mortality risk in UK Biobank male participants under 60, after controlling for traditional underwriting risk factors.

For example, individuals averaging ~5,000 steps per day had an approximately 1.5 times higher mortality risk compared to those with ~11,000 steps per day (median step count value in this age group). Conversely, individuals with ~15,000 steps per day had an approximately 30% lower mortality risk compared to the median.

While the overall pattern was similar in adults aged 60 and older, the relationship appeared to be stronger in younger participants (data not shown). This association was generally consistent across all data subsets (i.e., proxy for standard, rated, and chronic disease lives; data not shown).

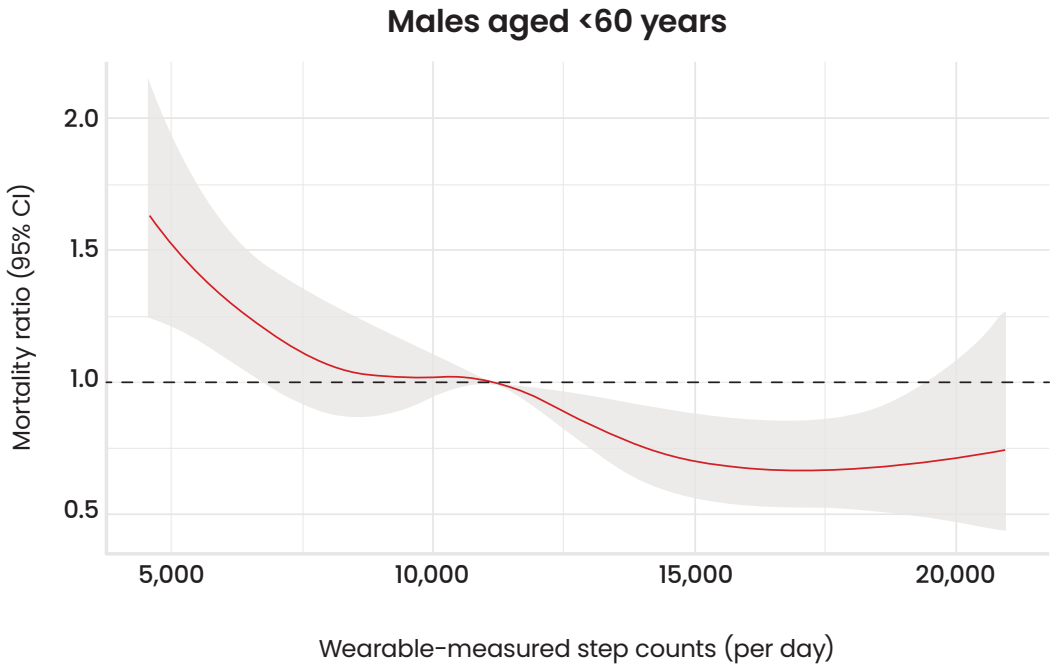

Figure 4
Wearable-measured step counts vs. all-cause mortality in all UK Biobank lives aged <60 years

Compared to published results from a recent meta-analysis,[15] our models, fitted to the various insurable populations, largely suggest that step counts have a slightly weaker impact on mortality. However, this is not surprising and is likely due to our inclusion of additional underwriting-relevant risk factors, which slightly attenuates the observed relationships.

Nonetheless, this remains an insightful and original finding, as this data comes from the largest objectively measured physical activity study in the world, with over 100,000 participants wearing wrist-worn accelerometers over a period of one week for 24 hours per day.

Figure 5 below shows the predictive power of replacing each traditional underwriting risk factor in the base model (i.e., BMI, smoker status, systolic blood pressure, and total cholesterol) with step counts in UK Biobank male participants under 60.

For example, the model's ability to predict mortality risk increased by over 1% once total cholesterol was replaced by step counts. Similar effects were observed for BMI and systolic blood pressure, suggesting that step count is a stronger predictor of mortality than BMI, systolic blood pressure, and total cholesterol in the UK Biobank cohort.

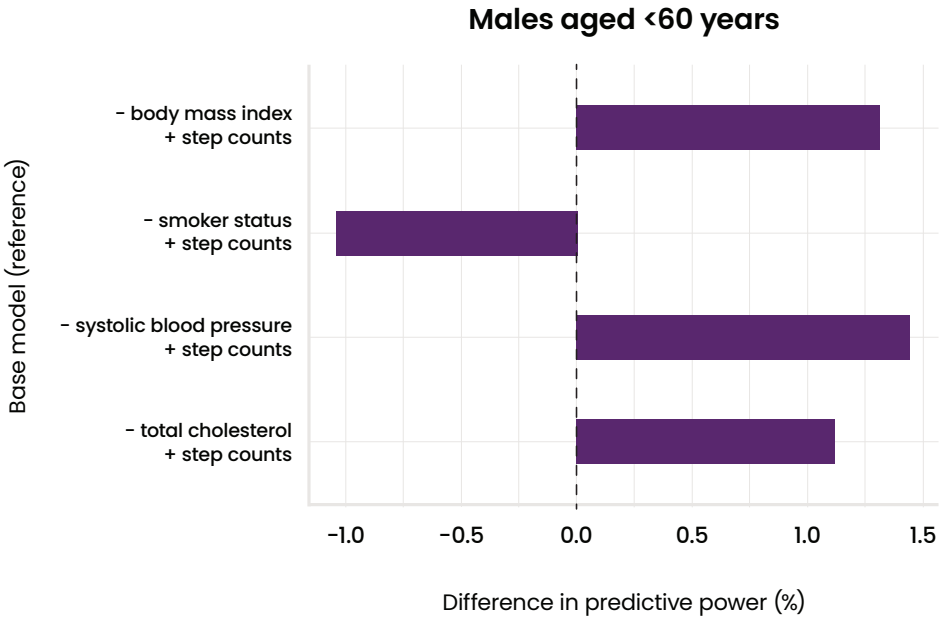

Figure 5
Quantifying the predictive power of individually replacing each traditional underwriting risk factor in the base model (i.e., body mass index, smoker status, systolic blood pressure, and total cholesterol) with self-reported walking pace in all UK Biobank male lives aged <60 years

Model accuracy decreased when smoker status was replaced with step counts – suggesting that smoker status is a more important predictor of mortality in the UK Biobank cohort. Findings were indistinguishable across the different subsets of the data (i.e., older lives as well as proxy for standard, rated, and chronic disease lives; data not shown).

Implications

The findings from our UK Biobank study, in partnership with the University of Leicester, have clearly demonstrated that:

a) BMI, self-reported walking pace, and wearable-measured step counts are significant and powerful predictors of all-cause mortality – findings that are applicable to insurable lives

a) Wearable-measured step counts, in particular, could replace most traditional underwriting risk factors without reducing risk differentiation and may even improve risk segmentation

BMI plays a fundamental part in underwriting life and health insurance, while metrics such as self-reported walking pace and step counts have yet to be fully integrated into underwriting practices. Our findings regarding low BMI values are especially thought-provoking. Still, even though some insurers may already be aware of this, further research is needed before recommending broader underwriting changes.

On the other hand, as the industry increasingly seeks new and alternative data sources for underwriting life and health insurance,[16] these findings provide compelling evidence on how self-reported walking pace and step counts can effectively segment mortality risk and complement traditional underwriting risk factors. These insights not only advance public health understanding of biometrics, healthy living, and mortality risks but also offer (re)insurers opportunities to refine underwriting philosophies and enhance wellness strategies.

Conclusion

In this paper, we have presented robust evidence on the prognostic value of BMI, self-reported walking pace, and wearable-measured step counts; findings that are highly applicable to insured lives. As the industry's interest in biometric data continues to grow, these insights have the potential to enhance underwriting and wellness strategies, while also helping applicants make informed decisions to improve their longevity.

Further insights from our ongoing research and collaboration with the University of Leicester are expected to be released later this year.

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Meet the Experts

Kishan Bakrania, Ph.D.

Kishan Bakrania is a Senior Biometric Data Scientist in RGA's Global R&D team. He primarily works with large health and insurance related databases to support underwriting, pricing, and product development, and is highly experienced in using advanced statistical and data science methodologies to deepen RGA's mortality and morbidity modeling capabilities. Prior to joining RGA in 2017, Kishan earned a doctorate in epidemiology from the University of Leicester and contributed to numerous peer-reviewed publications in prestigious medical and epidemiological journals. He holds a Master of Science in medical statistics, and a Bachelor of Science in mathematics from Leicester.

Richard Russell, Ph.D.

Richard Russell is Vice President, Biometric Research in RGA's Global R&D team. He and his team provide specialist resources to enhance RGA's mortality and morbidity modeling capability, including actuarial pricing, underwriting research, and innovation projects. He holds a Bachelor of Science in biotechnology, a Master of Science in bioinformatics (with distinction), and doctorate in statistics are from Imperial College London. He has authored more than 30 peer-reviewed articles for journals such as The Lancet, BMJ Open, PLOS One, and Annals of Actuarial Science.

Tom Yates, Ph.D.

Tom Yates is a professor of physical activity, sedentary behaviour and health at the University of Leicester. He leads the Leicester Lifestyle and Health Research Group, which conducts comprehensive research on how movement behaviors can be leveraged to promote health throughout the lifespan in multi-ethnic groups living with or at-risk of long-term conditions, such as Type 2 diabetes. Based at the Diabetes Research Centre, Leicester General Hospital, Professor Yates' expertise spans the 5 S's (sleep, sedentary behaviour, stepping, sweating and strengthening). He is also the Leicester lead for the Lifestyle theme of the NIHR Leicester Biomedical Research Centre.