Research: Epidemiology

Self-rated health scores predict mortality among people with type 2 diabetes differently across three different country groupings: findings from the ADVANCE and ADVANCE-ON trials

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Abstract

Aims To explore whether there is a different strength of association between self-rated health and all-cause mortality in people with type 2 diabetes across three country groupings: nine countries grouped together as 'established market economies'; Asia; and Eastern Europe.

Methods The ADVANCE trial and its post-trial follow-up were used in this study, which included 11 140 people with type 2 diabetes from 20 countries, with a median follow-up of 9.9 years. Self-rated health was reported on a 0–100 visual analogue scale. Cox proportional hazard models were fitted to estimate the relationship between the visual analogue scale score and all-cause mortality, controlling for a range of demographic and clinical risk factors. Interaction terms were used to assess whether the association between the visual analogue scale score and mortality varied across country groupings.

Results The visual analogue scale score had different strengths of association with mortality in the three country groupings. A 10-point increase in visual analogue scale score was associated with a 15% (95% CI 12–18) lower mortality hazard in the established market economies, a 25% (95% CI 21–28) lower hazard in Asia, and an 8% (95% CI 3–13) lower hazard in Eastern Europe.

Conclusions Self-rated health appears to predict 10-year all-cause mortality for people with type 2 diabetes worldwide, but this relationship varies across groups of countries.

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Introduction

Self-rated health is a measure that reflects a person's perception of his or her own health. A common way to measure self-rated health is through a single question asking people to rate their overall health on a scale from excellent to very poor [1]. Previous studies have consistently shown that self-rated health is an independent predictor of mortality, even after controlling for other objective health measures [1–3]; thus, self-rated health has been recommended for use as a routine indicator in clinical practice and risk assessment [4,5] and as an outcome variable in clinical trials [6,7].

Previous studies have reported that self-rated health is associated with mortality among people with diabetes mellitus [8,9]. The association has been found both for categorical measures of self-rated health (e.g. 'poor' health) and for health ratings scored on a 0–100 visual analogue scale (VAS) [10]. The VAS score is widely collected amongst people with diabetes, as it forms a component of the EQ-5D

> **What's new?**
>
> • Self-rated health is an independent predictor of mortality in people with diabetes.
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> • The visual analogue scale (VAS) score has a stronger association with mortality in Asia and a weaker association in Eastern Europe than in the 'established market economies' included in our study among people with type 2 diabetes.
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> • People with type 2 diabetes in different countries reporting the same VAS score can face different mortality risks.
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> • The VAS score can be a useful global health measure in clinical practice for people with type 2 diabetes, but adjustment would be required before it can be directly compared across countries and regions.

quality-of-life assessment instrument, which is routinely administered as part of many large multinational diabetes randomized controlled trials (RCTs) [10–12]. Although VAS information is collected, it is often not routinely reported or analysed, despite being a potentially useful risk predictor in people with diabetes.

Some previous studies have shown substantial variation across countries and regions in reporting on self-rated health which cannot be fully explained by differences in clinical risk factors and other patient characteristics [13–15]. However, it is less clear how the reporting differences impact on the relationship between self-rated health (including the VAS) and mortality when compared across different countries of the world.

In the present study, we used the Action in Diabetes and Vascular Disease: Preterax and Diamicron MR Controlled Evaluation (ADVANCE) trial and the ADVANCE Observation Study (ADVANCE-ON) [16,17], its post-trial follow-up, to examine the association between the VAS scores and all-cause mortality for people with type 2 diabetes across different country groupings.

Participants and methods

Data source

The ADVANCE trial (clinical trial reg. no. NCT00145925, clinicaltrials.gov) was a double-blind RCT, conducted by 215 collaborating centres in 20 countries between July 2001 and January 2008, involving 11 140 people with type 2 diabetes mellitus [16]. Participants were eligible for the study if they had type 2 diabetes diagnosed at age ≥30 years, were aged ≥55 years at time of entry to the study, and had at least one additional risk factor for cardiovascular disease. Participants were randomized, in a two-by-two factorial design, to either intensive blood pressure-lowering or placebo, and to

either intensive glucose control or usual care. The study outcomes consisted of macrovascular events, microvascular events and all-cause mortality. Details of the design of the ADVANCE trial have been published previously [16]. ADVANCE-ON was a follow-up study that continued observation of people who were alive after their randomized therapies ceased [17]. Post-trial follow-up was obtained from 8494 people out of a possible total of 10 082 participants (84%) alive when the trial finished from the sites that were not closed during the trial. Participants were censored at their last known alive date. Median follow-up, including in-trial and post-trial, was 9.9 years. A flow chart of the follow-up of study participants can be found in the Supporting Information (Fig. S1).

For the present study we analysed all participants in the ADVANCE trial (n=11 140), followed during both the in-trial and post-trial period, regardless of treatment assignment. A range of patient characteristic and clinical risk factors was obtained from the ADVANCE trial and used as controlling variables in statistical models, including age, gender, duration of diabetes, years of education, HbA_{1c}, systolic blood pressure, BMI, total cholesterol, HDL cholesterol, smoking and drinking status, history of major macrovascular or microvascular events, and allocation into glucose or blood pressure treatment group. Clinical risk factors (HbA_{1c}, blood pressure, lipids) were collected at week 2 after randomization, then at months 1, 2, 3, 4 and 6, and every 3 months thereafter in the treatment group; and at 3, 4 and 6 months after randomization, and every 6 months thereafter in the control group [16]. Patient-reported health status was measured using EuroQol VAS [18], a questionnaire-based thermometer-like scale, with zero representing the worst and 100 the best imaginable health state. Participants were instructed to draw a line on the scale to indicate 'how good or bad your own health is today, in your opinion' [18]. The VAS was administered on four occasions in the ADVANCE trial: at baseline; at the 24-month and 48-month visits, and on the final visit, occurring on average 5 years after randomization. Six participants out of 11 140 who did not report a VAS value at baseline were dropped from the analysis. The outcome of interest in this study was all-cause mortality.

As in previous analyses based on ADVANCE [15,19], the primary comparison in the present study was between three groupings of countries based on geography and economic development: Asia, comprising China, India, Malaysia and the Philippines; Eastern Europe, comprising the Czech Republic, Estonia, Hungary, Lithuania, Poland, Russia and Slovakia; and 'established market economies', comprising Australia, Canada, France, Germany, Ireland, Italy, the Netherlands, New Zealand, and the UK. This classification was made according to a standard definition which involves a combination of criteria including geographical proximity, and ethnic and socio-economic similarities [19].

Statistical analysis

We first estimated differential effects of country groupings on VAS scores in multivariable linear regression, controlling for patient characteristics and clinical risk factors. All the VAS score measures in the trial were used as individual observations, with the covariates updated to their current value (for age and duration of diabetes) or the most recent measurement (for clinical risk factors). To allow correlations among repeated measures in the same individuals, we clustered the regression on individuals to compute robust standard errors for coefficients.

We next analysed the association between VAS score and all-cause mortality using survival analysis. First, we examined the cumulative incidence of all-cause mortality in two strata defined in terms of baseline VAS scores in either the lower half or upper half of reported values. We next analysed the VAS score as a continuous variable using Cox proportional hazard models to examine the association between a 10-point increase in the VAS score and all-cause mortality after controlling for other patient characteristics and risk factors. Variables with measurements at different time points were included in the Cox model as time-dependent covariates. The linearity assumption of the VAS score was checked and confirmed with a Martingale residuals plot. The proportional hazard assumption for all predictors was examined using Schoenfeld residuals. History of major macrovascular or microvascular events did not fit the proportional hazard assumption, so was used as a stratification factor in the survival analysis. The no-interaction assumption (between the stratification factor and other variables) was examined using a likelihood ratio test before stratification. Adjusted hazard ratios (HRs) and 95% CIs were estimated. Relative hazard reduction was computed as (1-HR)*100. To evaluate whether the VAS score had different strengths of association with mortality across countries, we included an interaction term between VAS score and an indicator variable for each country group in the regression, and performed Wald tests to investigate the homogeneity of HRs for the interaction terms.

We further standardized the VAS score by calculating a z-score based on each country grouping's mean value and standard deviation (SD). The standardized VAS score was then used in the above Cox regression instead of the original score to remove the potential effect of different distributions of the VAS score on its cross-country association with mortality.

Five-year survival probabilities for people from different country groupings and with different VAS scores were predicted based on the estimated Cox regression. Other risk factors were fixed at their mean levels in the sample to standardize variation across country groupings in population characteristics. To compare the strength of association between the VAS score and mortality with analogous associations for other risk factors, 5-year survival probabilities for cigarette (and pipe) smoking were also estimated for each country grouping (with VAS score and other risk factors fixed at their mean level). The 95% CIs of 5-year survival probabilities were estimated through 1000 bootstrapped replications.

All analyses were conducted using STATA 14.1 (StataCorp LP, College Station, TX, USA).

Ethics

Approval to conduct the ADVANCE trial was obtained from the ethics committee of each study centre involved.

Results

Table 1 summarizes baseline characteristics of the study population, stratified into the following country groupings: established market economies (*n*=4862), Asia (*n*=4136) and Eastern Europe (*n*=2142). The mean (SD) VAS score at baseline for the overall study population was 76.4 (15.6), with the highest score reported in Asia [79.9 (13.5)], the lowest reported in Eastern Europe [67.7 (16.2)], and with established market economies in between [77.3 (15.6)]. After controlling for patient characteristics and clinical risk factors in the multivariable linear regression model, country grouping remained independently associated with the reported VAS score. Compared to people in established market economies, people in Asia on average reported 3.0 (95% CI 2.4–3.6) points higher on the VAS, while people in Eastern Europe on average reported 9.1 (95% CI 8.4–9.8) points lower.

During the follow-up, in total 2265 (20.3%) deaths were observed: 1136 (50.1%) from the established market economies, 720 (31.8%) from Asia, and 409 (18.1%) from Eastern Europe. The median (interquartile range) follow-up time in these three country groups was 9.9 (3.8), 10.5 (2.4) and 5.1 (4.5), respectively. Figure 1 shows the observed cumulative incidence of all-cause mortality for people reporting different levels of VAS score. People who reported a VAS score ≥80 (the median value at baseline) had a significantly lower risk of mortality over time relative to people who reported a score <80 [HR 0.62 (95% CI 0.55–0.70) in established market economies; HR 0.48 (95% CI 0.42–0.56) in Asia; HR 0.67 (95% CI 0.54–0.80) in Eastern Europe]. After controlling for other risk factors, a 10-point increase in VAS score was found to be significantly associated with reduced all-cause mortality in all three country groupings; the associated relative reduction in the mortality hazard was 15% (95% CI 12–18; *P*<0.001) in established market economies, 25% (95% CI 21–28; *P*<0.001) in Asia, and 8% (95% CI 3–13; *P*=0.004) in Eastern Europe (Fig. 2). The VAS score had a significantly (Wald test *P*<0.001) stronger association with mortality in Asia and a significantly (Wald test *P*=0.024) weaker association in Eastern Europe when compared to established market economies. A similar cross-country group difference was found by using the standardized VAS score (Fig. 2).

Table 1 Baseline characteristics in the ADVANCE population by region

	Established market economies (*n*=4862)	Asia (*n*=4136)	Eastern Europe (*n*=2142)
Age, years	67.1 ± 6.4	64.5 ± 5.7	65.3 ± 6.9
Women	1614 (33.2)	1926 (46.6)	1193 (55.7)
Duration of diabetes, years	6 (3-11)	8 (3-12)	7 (3-12)
Age at completion of highest level of formal education, years	17.8 ± 7 .3	18.3 ± 7.5	20.2 ± 6.5
HbA$_{1c}$			
mmol/mol	56 ± 13	62 ± 19	60 ± 19
%	7.3 ± 1.2	7.8 ± 1.8	7.6 ± 1.7
Systolic blood pressure, mmHg	146.1 ± 20.7	141.1 ± 21.7	150.0 ±21.7
BMI, kg/m^2	30.0 ± 5.3	25.3 ± 3.4	30.6 ± 5.0
Serum total cholesterol, mmol/l	4.9 ± 1.0	5.3 ± 1.2	5.7 ± 1.3
Serum HDL cholesterol, mmol/l	1.2 ± 0.3	1.3 ± 0.4	1.3 ± 0.3
Current smoking	627 (12.9)	561 (13.6)	362 (16.9)
Current drinking once a week or more	2477 (50.9)	411 (9.9)	508 (23.7)
History of major macrovascular events	1558 (32.0)	1261 (30.5)	771 (36.0)
History of major microvascular events	3910 (80.4)	3335 (80.6)	1666 (77.8)
Visual analogue scale score	77.3 ± 15.6	79.9 ± 13.5	67.7 ± 16.2

Data are means ± SD, *n* (%), or quartile 2 (quartile 1–quartile 3), unless otherwise indicated.

Based on the estimated Cox regression, a difference in VAS score from 30 to 100 was associated with a difference in 5-year predicted survival probabilities of 93.2% to 97.7% in the established market economies, 90.0% to 98.6% in Asia, and 93.2% to 96.2% in Eastern Europe (Fig. 3). For comparison, the difference in predicted 5-year survival probabilities between a smoker and non-smoker (all else being equal) was 95.7% to 96.7%, equivalent to the differences between a person with a VAS score of 60 vs 77 in the established market economies. The corresponding smoking/non-smoking equivalence in VAS scores was 66 and 76 in Asia, and 45 to 80 in Eastern Europe (Fig. 3).

Discussion

In the present study, we used data from the ADVANCE and ADVANCE-ON studies to examine the self-reporting of VAS score and its relationship with all-cause mortality in people with type 2 diabetes across three different country groupings in the world. We found that, after controlling for other clinical risk factors and patient characteristics, people with type 2 diabetes in Asia tended to report higher VAS scores compared to people with type 2 diabetes in the established market economies, whilst people with type 2 diabetes in Eastern Europe tended to report lower VAS scores. The VAS score was an independent predictor of mortality in all three country groupings among people with type 2 diabetes, whilst its association with mortality was stronger in Asia and weaker in Eastern Europe when compared to the established market economies.

Several studies have examined the relationship between self-rated health and mortality in individuals with diabetes [8,9,20]. Self-rated health has been found to be a predictor of mortality in people with diabetes from Australia and New
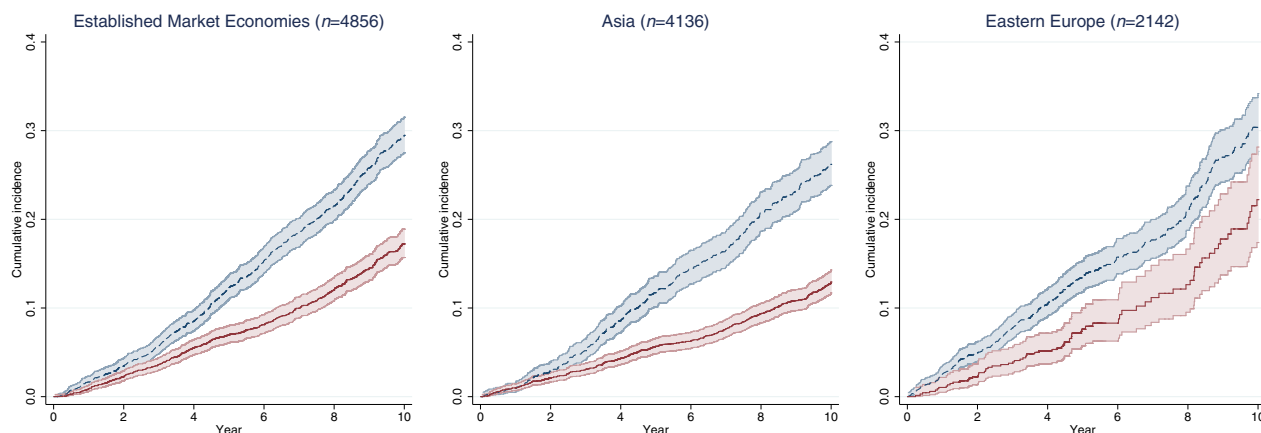

FIGURE 1 Cumulative incidence of all-cause mortality for people reporting relatively low (< 80) and high (≥80) visual analogue scale (VAS) scores. Dashed line: VAS score <80; solid line: VAS score ≥80.
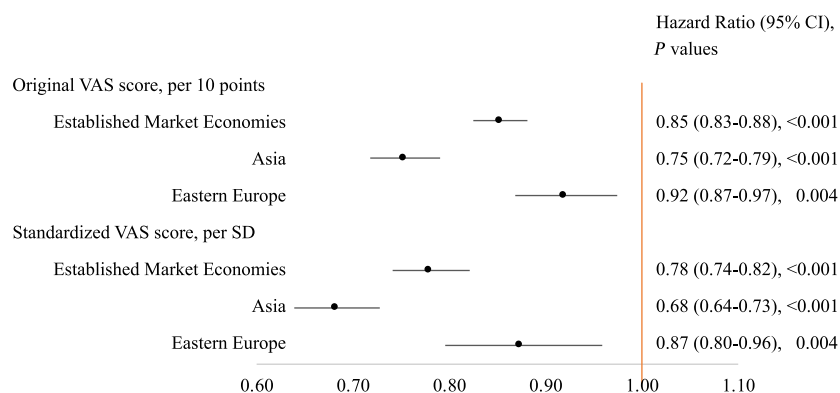
FIGURE 2 Hazard ratios of visual analogue scale (VAS) score's change in all-cause mortality, stratified by history of major macrovascular or microvascular events and adjusted for age, gender, duration of diabetes, education, HbA_{1c}, systolic blood pressure, BMI, total/HDL cholesterol, smoking, drinking, randomized treatment groups. No interaction was found between VAS score and history of major vascular events. Models were run on a total sample of 11 122 individuals with complete data. Education was missing for 10 participants, duration of diabetes for two participants, and VAS score for six participants.
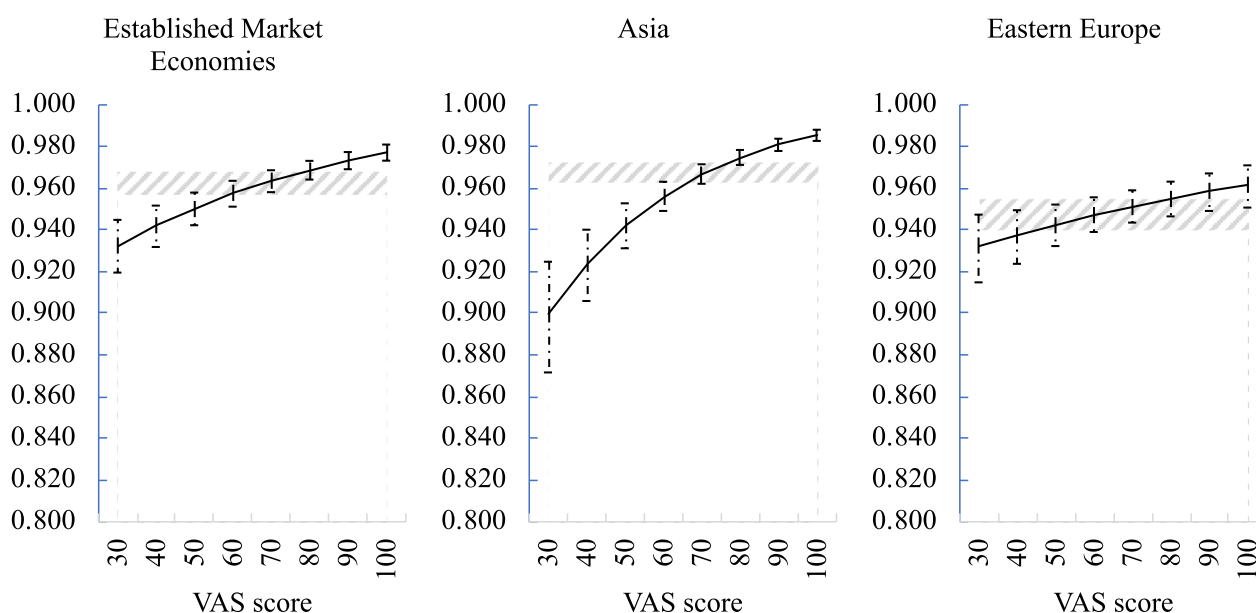

FIGURE 3 Estimated 5-year survival probabilities with different visual analogue scale (VAS) scores*, for people without previous major vascular events. Shadowed area represents the average 5-year survival probabilities for smoking (lower bound) and non-smoking (upper bound) participants in each country grouping.*Probabilities for VAS scores <30 are not reported due to the low number of individual reported scores in this range (< 1%).

Zealand [20], the USA [8], Germany, Netherlands and Sweden [9]. The variation in study design, methodology and cohort characteristics in these studies makes direct comparison of the strength of association between self-rated health and mortality across these studies difficult. In this study, the multi-country design of the ADVANCE trial allows us to compare the relationship between a specific self-rated health measure (the VAS) and mortality in people with type 2 diabetes across groups of countries.

There is an important practical implication of this study. In the present study, we calculated the 5-year survival probabilities on different VAS scores by country groupings, which provides a straightforward metric for clinicians and those involved with assessing the health of people with type 2 diabetes. It also highlights the difference across country groupings when people report the same VAS score. As shown by the 5-year survival probabilities, due to the different strength of association between VAS score and mortality across countries, people with type 2 diabetes from different countries reporting the same VAS score can face different future survival probabilities. For example, people with type 2 diabetes in Asia who report a lower VAS score are more likely to have a lower survival probability compared to people in the established market economies and Eastern Europe, which is worth paying more attention to in clinical settings. As a result, further recalibration is required on the

VAS score before it can be used as a measure for global health and compared directly across different countries. Given that patient-reported outcomes are now being advocated for use in medical research [21] and clinical practice [22], this should become a research priority for future studies.

As a measure of self-rated health that can be applied globally, the VAS has some advantages over other health status descriptors (e.g. rating of health as 'good') as the numerical scale does not require translation into different languages. Further, as previously mentioned, its inclusion in the generic health status measure, the EQ-5D, means that it is likely to be available in many diabetes studies as well as broader population health surveys [23,24]. Hence, there should be additional sources of data to both test our findings and analyse the sensitivity of VAS on predicting mortality in other populations and in other regions of the world.

Previous studies have shown that self-rated health can have a stronger association with cardiovascular events and mortality relative to other biomarkers, both in the general population [2] and in people with type 2 diabetes [10]. In this study, we compared the predictive ability of VAS score with regard to mortality with smoking, a strong traditional predictor of death in the diabetes population, and found it equated to relatively small differences in the reported VAS score, particularly in Asia. We were not able to compare the predictability offered by the VAS score with that of other classic methods such as the Charlson comorbidity index because the latter was not recorded in the ADVANCE trial. The advantage of using VAS scores in a clinical setting is that compared to those indices, the VAS score does not rely on information on a patient's past medical conditions and so it may be more convenient to measure.

The mechanism of self-rated health's predictive ability on mortality has previously been discussed but not yet fully understood [6,25]. Self-rated health may be related to some health behaviours which would impact on patient's survival. For example, it was found in a previous study that people with diabetes who viewed their health as poor were significantly less satisfied with the doctor–patient relationship [26], which may lead to worse treatment adherence. It is also possible that self-rated health can reflect some aspects of health that are not captured in the current clinical risk factors and patient characteristics, and the degree of this that can be reflected by self-rated health is different across countries and regions.

The main strength of the present study is that the analysis was based on a multi-country RCT with large sample size and long follow-up. This facilitated cross-country comparisons and helped to increase confidence in the results. A limitation is that the strict inclusion and exclusion criteria applied to the RCTs may lead to its sample differing somewhat from the general population; however, we have found the ADVANCE sample to have similar characteristics to community samples of people with diabetes in industrialized nations [27].

A limitation of the present study is that, apart from education, no other socio-economic characteristics were captured that could be included in the analysis. It has been shown in previous studies that people's subjective socio-economic status and social participation are strong predictors of self-rated health [28–30]. It will be interesting for future studies to investigate whether the cross-country difference with regard to reporting self-rated health still exists after controlling for a broader range of socio-economic characteristics. Including those factors into the analysis may also help to elucidate the reason for cross-country differences in self-rated health's strength of association with mortality.

In conclusion, in the present study we found that, after controlling for other clinical risk factors and patient characteristics, people with type 2 diabetes in different country groupings tended to report their VAS scores differently. The VAS score had a stronger association with mortality in Asia and a weaker association in Eastern Europe than in the established market economies. People with type 2 diabetes in different countries reporting the same level of VAS score may face a different future probability of death. Further recalibration is therefore required before self-rated health as reported via a VAS can be used as a global health measure and can be compared directly across different countries of the world.

Competing interests

M.W. reports consultancy fees from Amgen and Kyowa Hakko Kirin. P.H. has received honoraria from SERVIER for academic activities. S.H. reports lecture fees from Servier. J.C. has received research grants from the NHMRC and from Servier, administered through the University of Sydney, as principal investigator for the ADVANCE Trial and ADVANCE-ON post-trial study, and honoraria from Servier for speaking about these studies at scientific meetings. The remaining authors have no competing interests to declare.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Figure S1. Follow-up of study participants.