# Increases in blood glucose in older adults: the effects of spousal health

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## ABSTRACT

**Background:** The death or illness of a spouse negatively affects a partner's health, but little is known about how they affect blood glucose (glycemic) levels. This deficiency is surprising given that managing glycemic levels is vital to preventing or delaying the onset of diabetes, which is common among older adults. This study investigates (1) the extent to which a spouse's declining health is associated with changes in glycemic levels of older adults and (2) whether the association differs by sex.

**Methods:** Data come from a nationally representative longitudinal sample of 597 Taiwanese aged 54 and older in 2000. We use changes in spousal health and widowhood status to predict changes in glycosylated hemoglobin ($HbA_{1c}$) levels over a six-year period. Two types of longitudinal models—lagged dependent variable (LDV) and fixed effects (FE)—are estimated.

**Results:** In both the LDV and FE models, a decline in husbands' health is associated with increased $HbA_{1c}$ levels for women, but a decline in wives' health is not significantly associated with a change in $HbA_{1c}$ levels for men. The death of a spouse who is in very good health (dramatic declines in spousal health) is significantly associated with increased $HbA_{1c}$ levels for both sexes in the FE models.

**Conclusions:** To design effective interventions, health care providers should recognize that stressful life transitions may affect the glycemic levels of older adults. Sex-stratified interventions may be useful.



**Keywords:** Spousal health, blood glucose, sex, Taiwan

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**Abbreviations**

TLSA: the Taiwan Longitudinal Study of Aging

SEBAS: the Social Environment and Biomarkers of Aging Study

$HbA_{1c}$: glycosylated hemoglobin

FPG: fasting plasma glucose

LDV: lagged dependent variable

FE: fixed effects

## Introduction

Marriage benefits an individual's health in various ways, including having lower risks of acute and chronic illnesses [1] and greater longevity.[2] However, at older ages many married individuals, especially women, experience the death of a spouse—one of the most stressful life transitions.[3] Losing a spouse often leads to health declines[4] and increased risk of mortality,[2] but having an ailing or disabled spouse—which can be a chronic stressor—also has substantial adverse health consequences.[5,6] Spousal illness and death may be particularly challenging for older people, who may themselves be experiencing functional and cognitive declines.[7]

The greater health risks among older people whose spouse falls ill or dies may arise, in part, from their own physiological dysfunction. Compared with older adults have a healthy spouse, those who care for an ill spouse tend to have elevated blood pressure,[8] high triglycerides, low high-density lipoproteins,[9] and compromised immune response.[10] Similarly, for older adults, the death of a spouse is significantly associated with high blood pressure and elevated heart rate.[4] We know of only a few studies that have investigated the effect of a spouse's declining health on glycemic levels. These studies have found that being widowed, compared with cohabiting or being married, is associated with elevated glucose levels,[4] but no research has identified a significant association between spousal health and glycemic levels.[11,12] This shortcoming is surprising because (1) Type 2 diabetes is common among people aged 65 and older,[13] (2) glycemic control is vital to preventing or delaying the onset of diabetes and its complications,[14] and (3) diabetes-related morbidity and mortality and related health care expenses burden individuals, health care systems, and society as a whole.[15]

There are various reasons why older adults' glycemic levels may be associated with their spouses' health. One is the tendency to focus on their spouses' health at the expense of their own health (e.g., by allocating insufficient time for rest, exercise, or routine medical care).[16] Having a spouse fall ill may be particularly challenging for individuals who must perform multiple self-management tasks daily—including physical activity, dietary adjustments, and regular monitoring of blood glucose—to keep their glycemic levels under control.[17] Long-term or intensive caregiving may make a partner feel isolated and depressed, which may result in poor glycemic control.[18] In addition, during spousal illness or following the death of a spouse, individuals may lose some of the health-promoting benefits of marriage, including emotional support, health monitoring, and financial resources, [3] which help them to maintain their glycemic levels.[19]

Social norms and cultural expectations may differentially influence men's and women's glycemic levels as their spouses' health declines. The majority of (informal) caregivers are wives or daughters.[20] Compared with male caregivers, female caregivers allocate more time to caregiving,[21] receive little caregiving support,[22] and report higher levels of stress, emotional exhaustion, and physical symptoms.[23] Accordingly, women may have difficulty managing their glycemic levels when their spouse falls ill. Based on a nationally representative longitudinal sample of adults who are middle-aged and older, this study is the first to examine (1) the extent to which a spouse's declining health is associated with a change in glycemic levels and (2) whether the association varies by sex. Our findings shed light on how to improve social services and health-related interventions for older people who experience stressful life transitions.

## Methods

### Data

We use data from the Social Environment and Biomarkers of Aging Study (SEBAS), which is based on a random subsample of respondents from the Taiwan Longitudinal Study of

Aging (TLSA). TLSA is a national probability sample of persons aged 60 and older which began in 1989, with follow-up interviews approximately every three years. In 2000, a sample of respondents interviewed in the 1999 TLSA was selected to participate in SEBAS. Of the 1,497 people who completed in-home interviews, 68% completed a hospital-based physical examination. These individuals did not differ significantly from those who did not complete the examination in terms of sex, self-reported health status, or socioeconomic status.[24] In 2006, 639 of those who received a physical examination in 2000 participated in both a follow-up interview and a second physical examination.

The physical examination followed a similar protocol in both waves. Several weeks after the in-home interview, participants fasted overnight and provided a 12-hour overnight urine sample. The following morning, medical professionals collected blood samples and administered a medical examination at a nearby hospital. Completion rates for the protocol were high in both waves (≥ 88%).[25] Blood and urine specimens were analyzed at Union Clinical Laboratories in Taipei. The results of routine standardization and calibration tests indicated high intra-lab reliability for most biomarkers (e.g., glycosylated hemoglobin ≥ 0.96 in 2000 and ≥ 0.99 in 2006). Additional details about the study are provided elsewhere.[25] All protocols were approved by the Institutional Review Boards at Princeton University, Georgetown University, and the Bureau of Health Promotion, Department of Health, Taiwan.

Of the 639 respondents who received a physical examination in both waves, the analyses presented here exclude 42 respondents who never married; were cohabiting, divorced or formally separated; were married but did not report their spouses' health; or for whom glycemic measurements were missing.

**Measures**

We use data from the 2000 and 2006 waves, designated $T_1$ and $T_2$ respectively, in the tables. In each wave, currently married respondents assessed their spouse's current health on a 5-point scale, ranging from very good to very poor. Respondents in the sample who were not currently married were widowed. A spouse's health status and death together define a predictor with six categories, which we present using two variables: (1) a linear score ranging from 0 for very good to 4 for very poor health, after checking that the linearity assumption was appropriate, and (2) a dummy variable for widowhood. For widowhood, the reference cell is a spouse in "very good health." We present two coefficients representing the effects of (1) spouse's deteriorating health and (2) becoming widowed compared with having a spouse in very good health.

The SEBAS data include two glycemic biomarkers: fasting plasma glucose (FPG) and glycosylated hemoglobin ($HbA_{1c}$), a measure expressed as a percentage of the amount of sugar bound to hemoglobin in red blood cells. An $HbA_{1c}$ range of 5.7 to 6.4% is identified with pre-diabetes; anything greater ($\geq 6.5\%$) is considered as a diagnostic criterion for diabetes.[26] We focus on $HbA_{1c}$ because (1) $HbA_{1c}$ captures chronic hyperglycemia better than FPG, (2) $HbA_{1c}$ is less sensitive to non-compliance with fasting and (3) $HbA_{1c}$ has lower biological variability within an individual across assessments.[27] Nonetheless, we also estimate all models using FPG and report differences in results in the discussion. We include age and education (years of schooling) as control variables.

**Statistical analyses**

We consider two key statistical issues. First, changes in glycemic levels and spousal health and death between waves may vary by glycemic levels at $T_1$. For example, individuals who were aware of their high glycemic levels at $T_1$ may have expended greater effort at glycemic control and thus may exhibit a smaller increase in $HbA_{1c}$ levels. Thus, we take into account glucose levels of each respondent at $T_1$. Second, husbands and wives often have similar socioeconomic backgrounds, which may affect their choice of leisure activities and exposure to risk factors (e.g., poor eating habits, drinking, and smoking).[28,29] Therefore, the observed direct association between spousal health and glycemic control may result in part from shared risk factors, many of which are unobserved. To deal with these methodological issues, we estimate two types of longitudinal multiple regression models: a lagged dependent variable (LDV) model (to address initial glycemic levels) and a fixed effects (FE) model (to address unobserved factors).

These models have a useful bracketing property that may help capture the true effect of interest.[30] Suppose a decline in spousal health of one point in our scale actually increases $HbA_{1c}$ levels by $\delta$ percentage points. If the FE model is correct and there are persistent unobserved factors that lead to deteriorating spousal health, but we mistakenly fit an LDV model, then the estimated effect will tend to be too big ($\delta_{LDV} > \delta$). On the other hand, if the LDV model is correct and the respondent's baseline glycemic levels are associated with deteriorating spousal health, but we mistakenly fit a FE model, then the estimated effect will tend to be too small ($\delta_{FE} < \delta$). Under these circumstances the true effect will fall between the FE and LDV estimates. One would, of course, like to consider a more general model that includes these possibilities as special cases, but more than two waves would be needed.

Because there are sex differences in the association between spousal health and glycemic levels, we construct sex-stratified models. Nonetheless, we also explicitly test whether the association significantly differs by sex by pooling data from both sexes and testing the significance of interaction terms.

## Results

Table 1 presents descriptive statistics for all variables used in the analysis. Table 2 shows results from the LDV models, which control for initial glycemic level. We observe that changes in glycemic levels by spousal health vary by sex ($p < 0.05$, not shown). For women we find that a deterioration of husband's health of one step is associated with a significant increase of 0.13 percentage points in $HbA_{1c}$ levels between waves ($p < 0.05$, model 2) but find no significant increase in $HbA_{1c}$ levels after losing a husband in very good health ($p = 0.07$, model 2). For men we find no significant difference in glycemic levels by spousal health or becoming widowed (model 3). In all cases the estimates are adjusted for all other predictors in the model. For both men and women we find that changes in glycemic levels are significantly negatively associated with baseline levels, thus confirming the importance of controlling for the lagged outcome. Baseline spousal health status and death, however, are not significant in any model.

[Table 1 here]

Table 3 shows results from the FE models. Again, we find that the differences of interest vary by sex ($p < 0.05$, not shown). For women we find that a deterioration of husband's health of one step is associated with a significant increase of 0.15 percentage points in $HbA_{1c}$ levels ($p < 0.01$, model 2) and that losing a husband in very good health is associated with a significant increase in glycemic levels of 0.76 percentage points ($p < 0.001$, model 2). For men we find no significant effect of wife's deteriorating health—similar to LDV results—but we find a significant effect of widowhood, with an estimated increase of 0.64 percentage points after losing a wife in very good health ($p < 0.05$, model 3). These results, however, do not allow the changes in $HbA_{1c}$ to depend on initial $HbA_{1c}$ levels.

[Table 2 here]

For women, the effect of deteriorating husband's health is consistently estimated as an increase of 0.13 − 0.15 percentage points in $HbA_{1c}$ levels by both strategies. The consequences of widowhood, however, are less clear, but, if these models bracket the true effect, losing a husband in very good health would result in an increase in $HbA_{1c}$ levels between 0.31 and 0.76 percentage points. For men we consistently find no changes in glycemic levels when the wife's health deteriorates, but losing a wife in very good health increases $HbA_{1c}$ levels between 0.10 and 0.64 percentage points. In the LDV model for women, the effect of husband's health deteriorating from very good to very poor is 0.52 percentage points (0.13×4), whereas the point estimate of the effect of losing a husband in very good health is only 0.31. In contrast, the FE model for women produces a difference of 0.60 percentage points (0.15×4) when husband's health goes from very good to very poor, as compared with 0.76 when a husband in very good health dies. In all cases there seems to be very little increase in a woman's $HbA_{1c}$ levels when she loses a husband in very poor health.

[Table 3 here]

## Discussion

Only a few studies have investigated the effect of declining spousal health on changes in glycemic levels for older adults. Our study has several advantages over these studies. First, while prior studies used a clinical sample with a small sample size[12] or a population-based study based on cross-sectional data, [4,11] we used a nationally representative longitudinal sample. Second, based on theories of how culture shapes expectations of the caregiving role,[31] we investigated whether sex moderates the association between spousal health and glycemic levels. Third, we employed two types of longitudinal multiple regression models (LDV and FE), which mitigate potential bias due to baseline glucose levels and unobserved time-invariant characteristics.

Several key contributions emerge from our findings. First, the association between declining spousal health and changes in glycemic levels differed by sex. Results from both models revealed that women whose husbands suffered a decline in health over the six-year period between survey waves experienced an increase in $HbA_{1c}$ levels. The greater the reduction in husbands' health, the greater was the increase in wives' $HbA_{1c}$ levels. In contrast, wives' health was not significantly associated with changes in $HbA_{1c}$ levels for men. Our findings follow a well-documented pattern, whereby spousal illness and disability in old age have a greater negative impact on women's than men's health.[23,32] Gender socialization—which explains gender differences in caregiving attitudes and behaviors[31 22]—may in part explain why spousal health has a larger impact on glycemic changes for women. Social and cultural contexts also help account for the association. In Chinese culture, families play a vital role in shaping the wellbeing of older people. Adult children (traditionally daughters-in-law) are expected to take care of an ailing parent.[33] Thus, when a married woman falls ill, her husband is unlikely to become her primary caregiver, although caregiving behavior may have changed recently owing to the rise of dual-career families and increasing utilization of nursing homes.[34]

We also found that the death of a spouse in very good health was significantly associated with an increase in glycemic levels for both sexes, but losing a spouse in very poor health was associated with little increase in glycemic levels. These findings are consistent with studies showing that the transition to widowhood has a negative effect on health[2] and that unanticipated spousal death may have an especially deleterious effect on the wellbeing of older adults.[35] Emotional distress following spousal death may affect glucose metabolism through stress hormones (e.g., catecholamines and cortisol), thus increasing glycemic levels.[36,37] In addition, adoption of negative coping strategies (e.g., heavy drinking) and loss of health-promoting benefits of marriage[3] may explain why spousal death is associated with increased glycemic levels. However, the social and behavioral pathways linking spousal death to glycemic levels may differ by sex. According to social control and support theories, marriage improves men's health through wives' health monitoring (e.g., health care utilization, physical activity, drinking alcohol, and smoking)[38] but improves women's health through increasing their financial status, which, in turn, grants them access to better health-management resources (e.g., health insurance).[39] Future studies should seek to better understand these mechanisms and how they differ by sex.

Because FPG is a marker frequently used to verify diabetic conditions,[26] we performed supplementary analyses using FPG in lieu of $HbA_{1c}$. We obtained similar results, though significance levels varied by model. The LDV models showed that a decline in spousal health was significantly associated with an increase in FPG for women only, but findings from the FE model were not significant (data available upon request). We suspect that the FE model using FPG produced more erratic results because FPG is sensitive to non-compliance with the need for fasting and generally has more measurement error than $HbA_{1c}$,[27] and FE estimates are especially subject to measurement error.[30]

Our study has several limitations. First, our findings are based on older cohorts in Taiwan, who lived in an era dominated by traditional caregiving attitudes; most older adults feel that women ought to be primary caregivers and that entering a nursing home is shameful.[34] Thus, our findings may not be generalizable to younger cohorts who may be more willing to utilize caregiving institutions. Second, because spousal heath was reported by a partner, the respondent's affective state and attribution tendencies may bias the results.[40] Reporting biases may vary by sex:  previous research suggests that women predict their spouse's health more accurately than men.[41] Third, estimates from both models will be biased due to unobserved time-varying characteristics and omitted variables. Finally, we cannot rule out reverse causality: a wife's elevated glycemic levels may lead to a decline in her husband's health. For example, a diabetic wife may serve her husband the same foods that caused her own blood sugar levels to spike, ultimately causing her husband's health to deteriorate. In supplementary analyses, we confirmed that elevated $HbA_{1c}$ for women at $T_1$ was not significantly associated with a decline in husband's health at $T_2$ (data available upon request). This finding, however, does not lead to a firm conclusion about causal direction. More data points would be needed to adequately test this issue.

As life expectancy increases, individuals will be more likely to have a spouse fall ill or die during old age. Some older people may be ill-equipped for such stressful life transitions and their after-effects. Our findings suggest that older women are particularly likely to experience increased glycemic levels if their husband's health deteriorates and that older adults who experience spousal death may have difficulty managing their glycemic levels. These findings have three implications for health interventions for older adults. First, health educators and medical professionals should be aware that older adults whose spouse falls ill or dies are at high risk for developing diabetes. Second, health care providers should consider targeting such older adults, encouraging regular medical check-ups to enable early detection and treatment of diabetes. Counseling and cognitive behavioral therapy, which can reduce perceived stress, may also help control glycemic levels. Third, to curtail harmful coping mechanisms, including disordered eating, poor sleeping habits, and drinking, sex-specific interventions may be useful. Such interventions would ultimately reduce the downstream individual and societal costs of later life challenges.

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**Table 1** Descriptive and summary statistics for variables used in the models, by sex

| Variables | Women (n = 266) | Men (n = 331) |
|---|---|---|
| *Predictors* | | |
| Spousal health at $T_1$, mean (SD) | 1.43 (1.05) | 1.70 (1.13) |
| Spousal health at $T_2$, mean (SD) | 1.64 (1.13) | 1.68 (1.11) |
| Change in spousal health between $T_1$ and $T_2$, mean (SD) | .21 (1.21) | -.02 (1.24) |
| Widowed at $T_1$, % | 32.33 | 8.46 |
| Widowed at $T_2$, % | 43.98 | 13.29 |
| Widowed between $T_1$ and $T_2$, % | 11.65 | 4.83 |
| | | |
| *Outcomes* | | |
| $HbA_{1c}$ (%) at $T_1$, mean (SD) | 5.72 (1.07) | 5.55 (.96) |
| $HbA_{1c}$ (%) at $T_2$, mean (SD) | 6.21 (1.05) | 6.14 (1.09) |
| Change in $HbA_{1c}$ (%) between $T_1$ and $T_2$, mean (SD) | .49 (.73) | .59 (.76) |
| | | |
| *Covariates* | | |
| Age at $T_1$ (years), mean (SD) | 65.97 (7.83) | 66.63 (7.73) |
| Education (years), mean (SD) | 3.77 (4.18) | 6.95 (4.48) |

Spousal health is based on respondents who had a spouse at both waves (287 men and 149 women) and ranges from 0 (very good health) to 4 (very poor health).
$HbA_{1c}$ = glycosylated hemoglobin.

**Table 2** Lagged dependent variable (LDV) models predicting change in $HbA_{1c}$ between two waves, by sex

| Variables | Model 1: Total (n = 597) | | Model 2: Women (n = 266) | | Model 3: Men (n = 331) | |
|---|---|---|---|---|---|---|
| | *B* (SE) | *P* | *B* (SE) | *P* | *B* (SE) | *P* |
| Change in spousal health between $T_1$ and $T_2$ | .039 (.033) | .235 | .129 (.052) | .014 | -.015 (.043) | .731 |
| Widowed between $T_1$ and $T_2$ | .176 (.132) | .184 | .311 (.172) | .072 | .095 (.216) | .660 |
| | | | | | | |
| Spousal health at $T_1$ | -.012 (.036) | .733 | .071 (.059) | .233 | -.055 (.047) | .239 |
| Widowed at $T_1$ | .100 (.103) | .332 | .227 (.138) | .101 | .028 (.170) | .870 |
| $HbA_{1c}$ at $T_1$ | -.223 (.029) | < .001 | -.231 (.039) | < .001 | -.211 (.042) | |
| Age at $T_1$ | -.013 (.004) | .001 | -.011 (.006) | .080 | -.013 (.006) | .016 |
| Female | -.114 (.067) | .088 | | | | |
| Education | .001 (.007) | .883 | .014 (.010) | .177 | -.009 (.009) | .351 |
| | | | | | | |
| Constant | 2.701 (.325) | < .001 | 2.307 (.457) | < .001 | 2.786 (.453) | < .001 |

*B* = unstandardized coefficient; SE = standard error; *P* = p-value.
$HbA_{1c}$ = glycosylated hemoglobin.

**Table 3** Fixed effects (FE) models predicting change in $HbA_{1c}$ between two waves, by sex

| Variables | Model 1: Total (N = 1194) | | Model 2: Women (N = 532) | | Model 3: Men (N =662) | |
|---|---|---|---|---|---|---|
| | *B* (SE) | *P* | *B* (SE) | *P* | *B* (SE) | *P* |
| Change in spousal health between $T_1$ and $T_2$ | .064 (.034) | .062 | .154 (.052) | .004 | .014 (.045) | .761 |
| Widowed between $T_1$ and $T_2$ | .636 (.154) | < .001 | .761 (.190) | < .001 | .636 (.266) | .018 |
| Constant | 5.672 (.071) | < .001 | 5.525 (.114) | < .001 | 5.757 (.089) | < .001 |

*B* = unstandardized coefficient; SE = standard error; *P* = p-value; N = the number of observations over two waves.
$HbA_{1c}$ = glycosylated hemoglobin.