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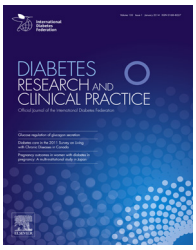

Education, glucose control, and mortality risks among U.S. older adults with diabetes

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ABSTRACT

Aims: Studies have shown that diabetes mellitus disproportionately afflicts persons of low socioeconomic status and that the burden of disease is greatest among the disadvantaged. However, our understanding of educational differences in the control of diabetes and its impact on survival is limited. This study investigated the associations among education, hemoglobin A_{1c} (HbA_{1c}), and subsequent mortality in adults with diabetes.

Methods: Prospective cohort data from the 2006, 2008, and 2010 Health and Retirement Study were linked with biomarker data for U.S. older adults with diabetes ($n = 3312$). Weighted distributions were estimated for all subjects at baseline and by the American Diabetes Association's general guidelines for HbA_{1c} control (<7.0% [53 mmol/mol] vs. ≥7.0% [53 mmol/mol]). Proportional hazard models were used to estimate educational differences in all-cause mortality by HbA_{1c} level with sequential adjustments for contributing risk factors.

Results: Mortality risks associated with $HbA_{1c} \geq 7.0\%$ [53 mmol/mol] were significantly greater in lower-educated adults than higher-educated adults ($P < 0.001$). We found that the hazard ratios (HR) associated with $HbA_{1c} \geq 7.0\%$ [53 mmol/mol] were highest among low-educated adults (HR = 2.18, 95% CI: 1.62, 2.94) and that a combination of socioeconomic, psychosocial, and behavioral factors accounted for most, but not all, of the associations.

Conclusions: Educational differences in HbA_{1c} control have significant implications for mortality and efforts to reduce these disparities should involve more vigilant screening and monitoring of lower-educated adults with diabetes.

1. Introduction

Diabetes mellitus and its complications are major causes of excess morbidity and mortality in the United States [1,2]. Nearly 20 million adults in this country have been diagnosed with diabetes and millions more are believed to be undiagnosed or exhibit prediabetes [3]. Effective medical care and disease management are critical for glycemic control and the prevention of poor outcomes from complications [4–7]. Yet,

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there remain cumulative shortfalls in the numbers of diabetic adults who are diagnosed, properly treated, and achieve recommended control, which have enormous human and financial costs [8–10]. Furthermore, those who are socioeconomically disadvantaged may be most susceptible to this cascade of inadequate care and control [10].

Studies have shown that diabetes disproportionately afflicts individuals of low socioeconomic status (SES) [11,12] and that the burden of disease is greatest among those with low education [13,14] and income [15–17]. Although the association between low education and mortality has been documented in adults with diabetes [18–21], evidence is limited in how hemoglobin A_{1c} (HbA_{1c}) contributes to educational differences in mortality. For adults with low education, adherence to the American Diabetes Association's (ADA) recommended guidelines for the treatment of diabetes is often difficult to achieve because of limited financial assets, reduced access to health care, inadequate psychosocial resources and support, and poor health behaviors [8,14,22]. Consequently, adults with diabetes and low education are at high risk for cardiovascular complications, kidney disease, and an overall shortened lifespan [15,22,23]. However, it remains unclear to what extent glycemic control is contributing to survival differences and the potential factors underlying these disparities.

This study is the first nationally representative examination of educational differences in ADA's recommended glycemic levels and the factors contributing to survival differences in U.S. older adults with diabetes. Using prospective cohort data that were linked to biomarker data, we first examined educational differences in levels of HbA_{1c} and then described the characteristics of study subjects by the ADA's recommended levels of HbA_{1c} (within general guidelines [<7.0% {53 mmol/mol}] vs. not within guidelines [≥7.0% {53 mmol/mol}]). We then used multivariate models to examine the direct and interactive associations among education and guideline levels for HbA_{1c} on all-cause mortality and tested a wide range of factors that may have contributed to the associations. The implications of the findings are discussed.

2. Methods

2.1. Study population

This study used nationally representative data from the Health and Retirement Study (HRS) for analysis. The HRS is an ongoing prospective cohort study of U.S. older adults sponsored by the National Institute on Aging. The original HRS cohort included 9824 respondents born between 1931 and 1941 who have been interviewed biennially since 1992. The initial participation rate was 82% and re-interview rates have been approximately 94% through 2010, with low rates of attrition due to nonresponse and lost tracking. Since 1998, the HRS has been supplemented with selective birth cohorts to replenish the nationally representative sample of older adults. Further details of the multistage sampling design, implementation, and response rates have been documented elsewhere [24].

In 2006 and 2008, HRS respondents were randomly selected to receive enhanced interviews that included physical measurements and a blood-spot sample to collect biomarker data. A random half-sample of respondents was selected in 2006 (n = 6735) and the other half-sample was selected in 2008 (n = 6329). Informed consent was obtained and blood samples were collected using standardized protocols for storage and shipment of specimens [25]. Assays were conducted for HbA_{1c}, serum cholesterol, and cystatin C. Assays for HbA_{1c} were performed using the Roche Unimate immunoassay and the Cobas Integra Analyzer, which were certified by the National Glycohemoglobin Standardization Program (NGSP). The Bio-Rad Variant high-performance liquid chromatography (HPLC) method, utilizing ion exchange HPLC to separate HbA_{1c}, was also NGSP certified [25]. The biomarker subsample included 12,418 adults aged 45 to 90 who provided consent and HbA_{1c} data for analysis. Subjects identified as having diabetes (n = 3312) were followed through 2010. The data were obtained through approval of a Restricted Data Use Agreement from HRS and the study protocol was deemed exempt from the Duke University institutional review board because the data were de-identified.

2.2. Measures

The classification for having diabetes was defined according to ADA's guidelines and as reported by the Centers for Disease Control and Prevention as $HbA_{1c} \geq 6.5\%$ (48 mmol/mol) or a reported diagnosis by a physician [8,26]. Comparisons with national rates of physician-diagnosed and undiagnosed diabetes ($HbA_{1c} \geq 6.5\%$ [48 mmol/mol]) from the National Center for Health Statistics (NCHS) are consistent with the rates obtained from our nationally representative sample of older adults for this time period (NCHS: 28.5% vs. HRS: 28.9%) [26]. Preliminary analyses showed that almost all of the subjects with diabetes had been diagnosed (90%) and that median HbA_{1c} levels were only slightly higher in the undiagnosed group than the diagnosed group (HbA_{1c} = 6.8% [51 mmol/mol] vs. 6.5% [48 mmol/mol], $P < 0.05$). There were no significant differences in education level between the undiagnosed and diagnosed groups. The recommended level of HbA_{1c} was defined as <7.0% (53 mmol/mol) (within guidelines) and ≥7.0% (53 mmol/mol) (not within guidelines) according to ADA's Standards of Medical Care for most people with diabetes [8].

The primary measure for educational attainment was categorized as less than high school education or high school education or more. Preliminary analyses considered alternative measures of education and showed that years of education were not normally distributed (with significant skewedness and kurtosis) and that additional categorizations of education did not improve model fit or change the substantive findings.

Demographic characteristics included age, sex, and race/ethnicity (Hispanic, non-Hispanic white, non-Hispanic black, or non-Hispanic other race). We also included covariates for several clinical factors to account for potential differences in underlying physiology. Clinical characteristics included time since diagnosis (years), insulin use (yes or no), obesity (calculated as weight in kilograms divided by height in meters squared ≥30.0; yes or no), blood pressure (<130/80 mmHg; yes or no), and non-HDL cholesterol (<130 mg/dL; yes or no) [8]. Because blood-spot samples were obtained from HRS participants who had not been fasting, LDL cholesterol levels could