Estimating Physician Effects on Glycemic Control in the Treatment of Diabetes: Methods, Effects Sizes, and Implications for Treatment Policy

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Running Title: Physician Effects in Diabetes

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ABSTRACT

Objective: Researchers have only just begun to investigate physician-related effects on medical outcomes. Such research is necessary for developing empirically-informed practice guidelines and policy. The primary goal of this study was to investigate if glucose management in type 2 diabetes varies by randomly-assigned physicians over the course of a year in treatment. A second goal of the study was to investigate if physician-related effects vary across differential patient characteristics. A tertiary goal was to investigate potential patient-level effects on glucose management.

Research Design and Methods: Hierarchical Linear Models (HLM) were used to investigate Hemoglobin A1c (HbA1c) among 1,381 patients, nested within 42 randomly assigned primary-care physicians at a VA medical center in the Southeastern United States. The primary outcome measure was change in HbA1c over the course of a year in treatment. On average, each study physician had 33 patients with diabetes.

Results: Overall, physician-related factors were associated with statistically significant but modest variability in HbA1c change (2%), while patient-level factors accounted for the majority of variation in HbA1c change (98%). Physician effects varied by patient characteristics, mattering more for Black patients, patients over 65, and patients whose glucose management improved over the treatment year.

Conclusion: The results of this study indicate that differential physician effects have minimal impact on glycemic control. Results suggest it is logical to support policies encouraging the development of patient-level behavioral interventions because that is the level which accounts for the majority of variance in glycemic control.
Diabetes affects approximately 20.8 million people in the United States or 7% of the population (1). Diabetes is associated with mortality, morbidity, increased health-care utilization, and increased health-care costs (1). Although comprehensive treatment can prevent or delay complications from diabetes (2-5), data indicate that glycemic control in patient populations is poor (6) and that diabetes care in the United States is often suboptimal (7).

Both patient and physician factors play roles in the successful treatment of diabetes. Recent studies indicate that a substantial proportion of diabetes management (e.g. diet, exercise, glucometer use, medications) is under the direct control of patients (8), however, the majority of medical care and education for diabetes is provided by primary care physicians (9,10). Thus, physician factors may substantially contribute to patient behavioral change and outcomes. The health care industry currently spends substantial resources tracking physician performance measures to address healthcare deficiencies and promote accountability (11-13). Consistent with this agenda, “pay-for-performance” policies are gaining popularity among insurance providers to encourage physicians to meet behavioral targets and avoid errors (14,15). Although it makes good sense to track administrative and procedural performance measures and to consider alternative ways of providing motivation to physicians, doing so is expensive and has not been conclusively shown to improve outcomes or change physician behavior (16).

There are few studies that have examined physician effects in diabetes outcomes (16). To address this gap in the literature, the current study used Veterans Health Administration data and Hierarchical Linear Modeling (HLM) to investigate glucose management as measured by Hemoglobin A1c (HbA1c) change over the course of a year in treatment. The primary goal of the study was to measure physician-related effects on HbA1c change while controlling for patient-level factors. A second goal of the study was to investigate if physician-related effects on HbA1c varied across patient characteristics (i.e., race, age, and health status). A tertiary goal of the study was to provide estimates for patient-level effects on HbA1c outcomes.

**Research Design and Methods**

**Sample.** We created a cohort of patients with type 2 diabetes at a VA medical center in the Southeastern United States using multiple patient files and existing Veterans Health Administration data sources. Individuals with type 2 Diabetes were identified based on having at least two ICD-9 codes for diabetes and having two or more visits each year since their diagnosis based on a previously validated algorithm (17). The cohort included 14,931 patients. For this study, we selected patients from the cohort who had at least 2 HbA1c measurements within a year apart and who had a specific designated primary care provider within the same period. To ensure reliability of study estimates, we excluded patients whose providers had less than 5 diabetic patients. The resulting dataset consisted of 1,381 patients, nested within 42 physicians. On average, each study physician had 33 patients with diabetes (sd=12.99).

**Demographics.** Patients in the study sample were 98% male. The mean age in the sample was 66 (sd=11) and the mean baseline HbA1c was 7.52 (sd=1.97). Race and ethnicity measures were aggregated to create three racial/ethnic groups: non-Hispanic Whites (Whites, 52%), non-Hispanic Blacks (Blacks, 38%), and Hispanics, Asians, multi-racial, and unknown (Other, 10%).

**Demographics by Physician Specification.** Preliminary HLM analyses were used to investigate the distributions of patient...
characteristics among study physicians to assure random distribution and identify potential covariates. There were no statistically significant differences among physicians in regards to patient gender, minority status, systolic blood pressure, diastolic blood pressure, or weight. Statistically significant, though small, differences were found in baseline HbA1c (<1% of the variance), and percentage of patients over 65 (3% of the variance). Thus, both were identified as covariates in the full model.

**Primary Outcome Measure.** The outcome measure of interest in the current study was change in HbA1c from baseline. HbA1c measures the average percentage of blood glucose over the past two to three months, and is considered an index of how well glucose is being controlled. Complications from diabetes can be prevented or delayed if HbA1c levels are kept below 7% (18). For the current study, HbA1c was measured at baseline and again, an average of 12 months after baseline (mean=363 days, sd=36).

**Statistical Analyses.** HLM was used to address the current research questions because it allows variance in outcomes to be partitioned between patients and physicians. This is possible by the handling of error. In regular multiple regression models, prediction error associated with patient characteristics and prediction error associated with physician specification would be combined into one error term. In contrast, HLM allows each physician to have a unique intercept (and slope) for patient effects on outcomes. Thus, error attributed to patient effects and error attributed to physician effects are in different terms (19). Statistical analyses in the current study were performed using HLM6 software (20). VA data are well suited for such an analytic strategy since patients are randomly assigned to available physicians. This limits confounding factors by naturally encouraging (though not guaranteeing) an orthogonal relationship between patient and physician characteristics.

**Physician Effects.** To investigate the role of physician effects on HbA1c change, over and above patient-level factors, a hierarchical unconditional model was used. In HLM, such models are called “unconditional” because they do not include specific predictors. Their function is to partition variance in outcomes among level-one and level-two unit specifications (21). An unconditional model was used to test the null hypothesis that there was no variation in HbA1c due to physician-level factors. To do this, variance components, \( \sigma^2 \) and \( \tau \), were estimated for patient-level and physician-level error terms, respectively. The null hypothesis could be safely rejected if the variance component, \( \tau \), was significantly different from zero and significantly improved model fit. Significance for model fit was based on comparing pairs of model deviances distributed asymptotically on a chi-square distribution (20).

Given significant results, unconditional model effect sizes were estimated using Intraclass Correlations (ICC) consistent with the methods recommended by Bryk and Raudenbush (21). In a two-level hierarchical structure, the ICC is defined as the proportion of the total variance in the outcome variable that is between the level-two units, or \( R^2_{total} \) (19). In a hierarchical patient-physician model, the ICC represents the proportion of variance accounted for at the physician level. It follows then, that the remainder of the variance can be attributed to factors at the patient level, or to other unspecified nested factors.

**Physician Effects by Patient Characteristics.** To investigate if and how physician effects varied across patient populations, a simple effects design was used. Separate unconditional models were estimated for Blacks, Whites, Others, patients over 65 years-old, patients under 65 years-old, and patients who improved, stayed the same, or
got worse over the course of the treatment year. Patient improvement was defined as a 15%, or more, decrease in HbA1c from baseline (in the study sample, this averaged to a 1-point overall decrease in HbA1c). Patient worsening was defined as a 15%, or more, increase in HbA1c, and patient’s who stayed the same were defined as those whose HbA1c change was less than 15% in either direction.

**Patient Effects.** To investigate the role of available patient characteristics in diabetes outcomes, a step-wise random coefficients model was estimated. The model was constructed by adding specific patient-level predictors to the total-sample unconditional model. Predictors were entered in the following order: Baseline HbA1c, age, and race/ethnicity (Blacks, Whites, Others), with each race/ethnic distinction dummy coded and alternatively added for effect estimation. With the current sample size (N=1,381) it is assumed the coefficient estimates for patient age and race are reliable and valid for similar populations; however, mathematical coupling and regression to the mean pose potential threats to the precision of the correlation between baseline HbA1c and HbA1c change. Accordingly, baseline HbA1c is included as a peripheral control rather than as a definitive measure of the impact of initial disease on HbA1c change.

As mentioned, within an HLM framework, the ICC or $R^2_{\text{total}}$ indicates the amount of total variance accounted for by level-one and level-two factors, regardless of what those factors are. By adding specific predictors to each level, it becomes possible to estimate the $R^2_{\text{within}}$ and $R^2_{\text{between}}$. In the present study, $R^2_{\text{within}}$ was estimated for each level-one predictor in a manner consistent with the recommendations of Snijders and Bosker. It denoted what portion of the total variance attributed to patients could be accounted for by each patient predictor. $R^2_{\text{between}}$ was not estimated because no specific physician-level factors or characteristics were entered into the models.

**RESULTS**

**Physician Effects.** The mean HbA1c after a year in treatment was 7.21 (sd=1.68). Table 1 shows the estimated variance components ($\sigma^2=5.14$, $\tau=0.09$) for patient- and physician-level units in the overall-sample unconditional model. The value of $\tau$ was significantly different from zero and improved model fit ($\chi^2=71.77$, $df=41$, $p=.002$), indicating the presence of physician-level effects beyond patient-level factors. The intraclass correlation (ICC) was .02, indicating that 2% of the overall variance in HbA1c change over the study period could be accounted for by physician-level factors, and 98% could be attributed to patient-level, or unspecified, factors. As table 2 indicates, adding patient covariates of age, baseline HbA1c, and non-minority status to the unconditional model had no substantial effect on the ratio of variance accounted for by physician specification ($\Delta ICC=0.005$). Figure 1 shows the amount of variance in HbA1c change accounted for by patient and physician factors.

**Physician Effects by Race/Ethnicity.** The unconditional model for Black patients yielded a physician-level variance component ($\tau=.18$) that was significantly different from zero and improved model fit ($\chi^2=66.22$, $df=41$, $p=.02$), indicating the presence of physician-level effects beyond patient-level factors. The intraclass correlation indicated that 3% of the overall variance in HbA1c change for Blacks could be accounted for by physician-level factors. The unconditional model for Whites yielded a physician-level variance component ($\tau=.08$) that was not significantly different from zero and did not improve model fit ($\chi^2=55.52$, $df=41$, $p=.06$). However, marginally significant findings for Whites may have been due to a limited sample size rather than to true differences.
between groups. The non-significant intraclass correlation indicated that 2% of the overall variance in HbA1c change for Whites could be accounted for by physician-level factors.

**Physician Effects by Age.** The unconditional model for patients over 65 yielded a physician-level variance component ($\tau = .13$) that was significantly different from zero and improved model fit ($\chi^2 = 60.64$, $df = 41$, $p = .02$). The intraclass correlation was .02, indicating that 2% of the variance in HbA1c change for patients over 65 could be accounted for by physician-level factors. The unconditional model for patients under 65 yielded a physician-level variance component ($\tau = .01$) that was not significantly different from zero ($\chi^2 = 47.54$, $df = 41$, $p = .22$).

**Physician Effects by Change in HbA1c.** The unconditional model for patients who improved yielded a physician-level variance component ($\tau = .14$) that was significantly different from zero and improved model fit ($\chi^2 = 68.20$, $df = 41$, $p = .005$). The intraclass correlation was .05, indicating that 5% of the overall variance in HbA1c for patients who improved could be accounted for by physician-level factors. The unconditional model for patients who did not improve yielded a physician-level variance component ($\tau = .01$) that was not significantly different from zero ($\chi^2 = 48.37$, $df = 41$, $p = .17$). The unconditional model for patients who got worse yielded a physician-level variance component ($\tau = .00$) that was not significantly different from zero and hence did not improve model fit ($\chi^2 = 28.25$, $df = 40$, $p > .50$).

**TOTAL SAMPLE PATIENT EFFECTS**

**Baseline HbA1c.** The random coefficients model predicting HbA1c change estimated effects for patient HbA1c baseline, patient age, and patient race. The first factor entered into the model was baseline HbA1c. As table 2 indicates, baseline measurement significantly predicted HbA1c improvement over the course of the treatment year ($t = -31.94$, $df = 1380$, $p = .000$). Higher baselines were associated with greater decreases in HbA1c. The estimated $R^2_{\text{within}}$ was .46, indicating that baseline levels accounted for 46% of the patient-level variance in HbA1c change, or 45% of the total variance (46% of 98%).

**Patient Age.** Patient age significantly predicted HbA1c change over 12 months ($t = -2.27$, $df = 1380$, $p = .023$), after controlling for baseline HbA1c. Older age was associated with greater HbA1c improvement. The estimated $R^2_{\text{within}}$ was .004, indicating that patient age accounted for less than 1% of the patient-level variance in HbA1c change. Even so, the effect translated into measurable differences in health outcomes. A production function of the modeled age coefficient indicated that for a 55 year-old patient, age was associated with an improvement of 0.55 in HbA1c levels, while for a 75 year-old patient, the improvement was 0.75. This is an effect size of about a tenth of a standard deviation difference ($d = .09$).

**Patient Race/Ethnicity.** The three racial/ethnic groups were alternatively entered into the model. Controlling for baseline HbA1c and age, categorization as Black was not associated with significant change in HbA1c ($t = .15$, $df = 1380$, $p = .11$), and neither was categorization as Other ($t = .04$, $df = 1380$, $p = .70$). However, categorization as White was associated with significant improvement in HbA1c over the course of the treatment year ($t = -2.33$, $df = 1380$, $p = .02$). Because the predictor variable was dummy coded, indicating being White versus Black and Other, the effect is referred to here as Non-minority status. The estimated $R^2_{\text{within}}$ was .003, indicating that Non-minority status accounted for less than 1% of the patient-level variance in HbA1c change. The effect translated into a between-group difference of about a tenth of a standard deviation ($d = .09$).
Although in general, Black patients showed greater improvement than White patients, that difference appeared to be due to Black patients having higher HbA1c baselines. After baseline HbA1c was entered into the model, White patients showed greater improvement.

CONCLUSION

The primary goal of this study was to investigate if diabetes outcomes varied by randomly assigned physicians over the course of a year in treatment. Physician-level factors were associated with statistically significant but modest variability in health outcomes, accounting for 2% of the total variance in HbA1c change. Simple effects analyses revealed that physician factors mattered more for Black than White patients, and more for patients over 65 than those under 65. Interestingly, physician factors mattered the most for patients who got better over the year, accounting for 5% of the total variance in HbA1c change. Physician-level factors did not matter at all for patients who got worse. Significant patient-level predictors of HbA1c change were baseline HbA1c, age, and non-minority status. The results of this study suggest that physician effects only have minimal impact on glycemic control. These findings are consistent with the results of a prior study by Krein and colleagues (16). The researchers investigated 12,110 patients within 258 primary care physicians across 13 VA medical centers and found that physician effects accounted for 1% of total variance in HbA1c. The current study builds on those findings by examining change over time in HbA1c and by investigating how physician effects vary by patient characteristics.

The significance and meaning of the physician-level effect reported here (2% of the variance) depends on one’s perspective. Interpreting small effect sizes in large populations is often difficult. For example, in the U.S. population, Downs Syndrome accounts for a statistically significant, though very small, amount of variance in IQ scores. One cannot then interpret that to mean that Downs Syndrome is not an important factor in IQ. Likewise, although physician effects appear to play a relatively small role in overall HbA1c outcomes, for some individual patients, or groups of patients, physician effects may be particularly important for survival and quality of life.

Alternatively, from a policy-oriented perspective, 2% of the variance does not seem like a particularly fruitful target on which to focus limited resources and expensive interventions. Ninety-eight percent (98%) of the variance in HbA1c change in the current sample appears to be due to patient-level factors. Much of that variance is accounted for by largely unmutable factors, such as baseline disease, age, and race. However, a good deal of the variance (52%) remains to be explored and may very well be associated with potentially mutable factors.

The results of this study suggest it is logical to support policies encouraging the development of patient-level interventions because that is the level which accounts for the majority of variance in glycemic control. Moreover, significant progress has been made in the development of effective patient-oriented interventions. A systematic review of 72 Randomized Controlled Trials (RCTs) in patients with type 2 diabetes showed that self-management training improved diabetes knowledge, frequency and accuracy of glucose self-monitoring, and glycemic control (24). A meta-analysis of 31 RCTs found that self-management education decreased HbA1c on average by 0.76% (95% CI, 0.34 - 1.18) and the amount of decrease was highly correlated to the number of contact hours (25). Moreover, a recent meta-analysis of 25 RCTs investigating the effects of psychological interventions on HbA1c outcomes indicated improved outcomes for the experimental conditions in about half of the studies (26). It should be noted that these
effects were in addition to physician care. In essence, studies that found significant results did so by manipulating some factor within the “Unspecified Patient Effects” portion of figure 1. Given the current state of medical treatments, that portion is where the largest potential payoff for future interventions exists.

Results of the current study are particularly relevant in light of the recent movement toward patient empowerment in diabetes self-care (27-28). As noted, results indicated that physician factors mattered the most for patients who got better and not at all for patients who got worse. The patient-empowerment literature could offer one straightforward explanation for this differential effect--patients who feel empowered may engage with their doctors more overall, and as such, their doctors’ skills, talents, and characteristics have more of an opportunity to affect outcomes. In contrast, patients who do not feel empowered to manage their diabetes may be less engaged with their physicians and thus the skills and characteristics of their physicians may not come to bear on treatment outcomes. In such cases, “bad” treatment does not make patients worse, and “good” treatment does not make them better. However, for patients who improved, physician-related factors made a meaningful difference in how much or how little they improved.

This study has some limitations. First, it is important to note that “physician-level factors” are not synonymous with “physician characteristics.” Potential non-random factors associated with physician specification, such as nursing team allocation or the availability of facility resources may have the potential to bias estimates of physician-specific effects. Future investigations should take into account the ecology of hospital settings and sample from a variety of institutions. Second, there are important patient-level factors that were not available for this analysis. There is a need to further explore patient-level factors affecting diabetes outcomes, and future studies would benefit from including a broader range of patient-level predictors.

In conclusion, the results of this study suggest it is logical to support policies encouraging the development of patient-level interventions because that is the level which accounts for the majority of variance in glycemic control. Overall, results indicate a need for creativity in current treatment paradigms and policies, including the expanded use of multidisciplinary provider teams and behavioral approaches in the treatment of type 2 diabetes.

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REFERENCES


**TABLE 1**  
*Variance components for unconditional models: Physician effects on diabetes HbA1c outcomes*

<table>
<thead>
<tr>
<th>Random Effect</th>
<th>Variance Component</th>
<th>N</th>
<th>df</th>
<th>Chi-square</th>
<th>p</th>
<th>ICC (R^2_total)</th>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Patient: ( \sigma^2 )</td>
<td>5.14</td>
<td>1,381</td>
<td></td>
<td>71.77</td>
<td>.002</td>
<td>.02</td>
</tr>
<tr>
<td>Physician: ( \tau )</td>
<td>0.09</td>
<td>41</td>
<td></td>
<td>62.22</td>
<td>.018</td>
<td>.03</td>
</tr>
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<td>African American</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient: ( \sigma^2 )</td>
<td>6.57</td>
<td>528</td>
<td></td>
<td>62.22</td>
<td>.018</td>
<td>.03</td>
</tr>
<tr>
<td>Physician: ( \tau )</td>
<td>0.18</td>
<td>41</td>
<td></td>
<td>55.52</td>
<td>.064</td>
<td>NS</td>
</tr>
<tr>
<td>Caucasian</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient: ( \sigma^2 )</td>
<td>3.76</td>
<td>719</td>
<td></td>
<td>55.52</td>
<td>.064</td>
<td>NS</td>
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<tr>
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<td>0.08</td>
<td>41</td>
<td></td>
<td>60.64</td>
<td>.024</td>
<td>.02</td>
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<td>Over 65 years old</td>
<td></td>
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<td></td>
<td></td>
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<td></td>
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<tr>
<td>Patient: ( \sigma^2 )</td>
<td>3.97</td>
<td>718</td>
<td></td>
<td>55.52</td>
<td>.064</td>
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<tr>
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<td></td>
<td>60.64</td>
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<td>.02</td>
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<td>Under 65 years old</td>
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<tr>
<td>Patient: ( \sigma^2 )</td>
<td>6.04</td>
<td>663</td>
<td></td>
<td>47.54</td>
<td>.224</td>
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<tr>
<td>Physician: ( \tau )</td>
<td>0.01</td>
<td>41</td>
<td></td>
<td>48.37</td>
<td>.17</td>
<td>NS</td>
</tr>
<tr>
<td>Patients who improved †</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient: ( \sigma^2 )</td>
<td>2.74</td>
<td>461</td>
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<td>68.20</td>
<td>.005</td>
<td>.05</td>
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<td>Physician: ( \tau )</td>
<td>0.14</td>
<td>41</td>
<td></td>
<td>68.20</td>
<td>.005</td>
<td>.05</td>
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<tr>
<td>Patients who remained same</td>
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<td>Patient: ( \sigma^2 )</td>
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<td>48.37</td>
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<td>Physician: ( \tau )</td>
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<td>41</td>
<td></td>
<td>48.37</td>
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<td>NS</td>
</tr>
<tr>
<td>Patients who got worse</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient: ( \sigma^2 )</td>
<td>1.51</td>
<td>408</td>
<td></td>
<td>28.25</td>
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<td>40</td>
<td></td>
<td>28.25</td>
<td>&gt;.500</td>
<td>NS</td>
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</table>

* Variance components, \( \sigma^2 \) and \( \tau \), denote an estimate of the amount of variance in outcomes attributable to patient and physician effects respectively. While patient effects are assumed to account for variance in HbA1c outcomes, physician effects were tested with a chi-square statistic to compare the fit of models that included physician effects to null models without physician effects. A significant chi-square indicates rejection of the null hypothesis that patients outcomes do not vary by randomly assigned physicians. †Patients who improved were operationalized as patients whose HbA1c levels improved by 15% or more of baseline, patients who remained the same were those whose levels stayed within 15% of baseline, and patients who got worse are those whose HbA1c levels rose by more than 15% of baseline.
### TABLE 2

*Random coefficients model predicting A1c change (df within = 1,380, df between = 41)*

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Coefficient</th>
<th>Standard Error</th>
<th>T-ratio</th>
<th>p</th>
<th>$R^2_{\text{within}}$</th>
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<tr>
<td>Intercept</td>
<td>6.08</td>
<td>0.33</td>
<td>18.23</td>
<td>.000</td>
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<tr>
<td>A1c Baseline</td>
<td>-0.73</td>
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<td>-31.94</td>
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<td>.46</td>
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<td>Patient Age</td>
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<td>.004</td>
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<td>Non-Minority</td>
<td>-0.21</td>
<td>0.09</td>
<td>-2.33</td>
<td>.020</td>
<td>.003</td>
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<table>
<thead>
<tr>
<th>Random Effect</th>
<th>Variance Component</th>
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<th>p</th>
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<td>58.08</td>
<td>.040</td>
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<tr>
<td>Level One (r)</td>
<td>2.76</td>
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FIGURE 1. Total variance accounted for in HbA1c change by Patient and physician factors.