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Determinants of Adequate Control in Diabetic Patients; Application of Multilevel Analysis for Costa Rica

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Abstract

Aim: To establish an initial approach to identify individual and group variables that determine adequate interventions on diabetic patients by the Basic Integral Healthcare Units of the Costa Rican social security system.

Methods: The study design is non-experimental, cross-sectional and applies multi-level logistic regression. The data were obtained from a sample chosen from the Health Services Purchasing Direction, and includes diabetic patients cared for at local levels from January to December 2004. The information was used at 2 levels of analysis: level 1 (individual) and level 2 (group), and glycosylated hemoglobin was used as a dependent variable.

Results: Forty-nine percent of patients were controlled, with a median age above 60 years, 66% were women, and 76,6% had a body mass index reflecting overweight or obesity. On average, the Basic Integral Healthcare Units in the study had 7 years since initiating the reform process, and their average score on the "Commitment of Management" for the last 5 years was 87%. Moreover, the average population covered was 40 thousand inhabitants, and 22% of them had high school education. Multilevel logistic regression revealed that as diabetic patients age the probability of achieving control of the disease also increases. Women had a lower probability of being under control as compared to men. Diabetic patients belonging to the Basic Integral Healthcare Units that initiated their reform earlier, and those belonging to health services achieving higher scores on the "Commitment of Management" had a higher probability of being under control, even though this finding was not statistically significant, with respect to the other variables in the model.

Discussion: Approximately between 6% and 10% of the variance in the control of diabetic patients is explained by differences within local health services, after controlling for other intervening variables.

Key words: *Diabetes Mellitus*, glycosylated hemoglobin A, logistic models, Costa Rica

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Abbreviations: DM, *Diabetes Mellitus*; CCSS, Caja Costarricense de Seguro Social (Costa Rican Social Security Authority); HbA1c, glycosylated hemoglobin; BMI, body mass index; HA, health areas; EBAIS, Basic Integral Healthcare Unit; PQL, Penalized Quasilikelihood.

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In most developing countries, at least 10% of adult (35-64 years of age) deaths are attributable to *Diabetes Mellitus* (DM) reaching even 25% in some cases.[1]

In Costa Rica, prevalence of all cases of DM was estimated to be 4.6% during 1995 and 5% during 2000, with an expected augmentation to 7% for 2025. Chronic complications associated to DM progression entail high economic costs for treatment and maintenance of patients for both developed and developing countries.[2] The economic impact [a] of inadequate control of diabetic patients within Costa Rican health services was about ¢2.036 million (US $4,13 million) between 2001and 2003.[3] In 2004, hospital discharges were 338.716, 0,4% of which had DM as first or second cause. This represented an approximate expenditure of ¢1.027 million (US $2,05 million) [b]. In the first level of care around 250.821 consultations were given to diabetics, this meaning expenditures amounting to ¢2.032 million (US $4,06 million).

One of the most reliable indicators of adequate control of diabetic patients is the measurement of glycosylated hemoglobin (HbA1c) in blood because of the chronic adhesion of glucose to this protein in the red blood cells.[4]

In 1995, Costa Rica starts a process of reform of its healthcare system involving efforts to reinforce first level healthcare services through the transferral of infrastructure and human resources from the Ministry of Health to the *Caja Costarricense de Seguro Social* (CCSS), the Costa Rican Social Security Authority. The implementation of this process was not simultaneous throughout the country and it had not been finished yet by the end of 2004. The process required raising the numbers of staff and infrastructure, disaggregating the country's seven regions into 103 Health Areas (HA), and these into sectors, which are held responsible for providing basic healthcare to a population of about 4000 individuals. This must be achieved by a team known as the Basic Integral Healthcare Unit (EBAIS after its name in Spanish), consisting of a medic, a nursing assistant, a primary care technician and a medical registry technician.

One of the keystones of this reform in the search of a higher efficiency within the system is the so-called "Management Commitments". These documents are subscribed by the local health managers and establish goals and indicators of the process in order for resources to be assigned and follow up to be carried on.[5]

This work aims to identify the determinants of adequate control of the diabetic patient taking into account the patients' characteristics and the effect of the HA on this control.

[a] Measured as total admissions associated with healthcare situations capable of being resolved on the first level of care times the daily cost of these admissions.
[b] Exchange rate for the 14th of November 2005 according to Costa Rica's Central Bank, 492,45 colones per US dollar.

Materials and methods

This research is a non-experimental double analysis including a transversal one on diabetic patient-related variables and an ecological one on the variability of HbA1c measurements between the various HA. The data for this study were obtained by uneven conglomerate sampling of the 103 HA done during February and March 2005. Sectors of each HA represented the uneven conglomerates, which were adjusted taking into account the HA's total population. The initial sample is based on an unrestricted random sample, adjusted for the results of the previous years' evaluations. This sample is distributed proportionally to the amount of consultations that took place in the selected sector and this is used to perform an equal probability of selection method in order to avoid ponderation of results. Tests to determine whether if results were affected by these modifications in sampling or not were run. These tests showed minimal variation restricted to the last two decimals, thus giving consistency to the sampling method.

Conglomerate sample size ranged from 30 to 78 medical records, depending on the specific sector of each HA, with a non-response level of 5% and a confidence level of 90%. Selection of medical records was done randomly from the first time consultation listings of diabetic patients seen between January and December 2004.

The study comprises 5778 observations, of which those that lacked data on gender, age, BMI and HbA1c were excluded.
Data on HbA1c were selected from the second semester of 2004 and missing cases were substituted with data from the first semester of the same year. In the end, the data included 3 595 observations on diabetic patients seen in 81 of the 103 HA of CCSS.

Variables analyzed in this study show a two level-hierarchic structure. Level 1 includes variables associated with the diabetic patients whereas level 2 includes variables associated with the HA. For this reason, a multilevel design of the analysis was used.[6-9] Adequate control of the patient, determined by a level of HbA1c ≤ 7% following the American Diabetes Association criterion [10], was considered the dependent variable. Independent variables of level 1 were gender, age and

BMI, and those of level 2 were time since primary healthcare reform, hours-medic per 1 000 inhabitants, time and rate on "Management Commitment", type of HA, opening hours, healthcare pressure (percentage of population under 6 or over 64 years of age) and mean level of education of the population assigned to the HA.

Measures of central tendency, dispersion, proportions and frequencies were used for the descriptive analysis of the data.
Multivariate analysis uses multilevel logistic regression[11-12] whereby the void and random intercept models are estimated.

The void model does not include explicative variables and does a decomposition of variance in a component of variability within diabetic patients and HA in the same area. The random intercept model derives from the void model by the addition of explicative variables on each level of analysis.

Algebraically, the model is as follows:

$$\text{logit}(y_{ij}) = \beta_{00} + \sum_{k=1}^{K} \beta_{k0} x_{kij} + \sum_{h=1}^{H} \beta_{h0} z_{hj} + \mu_{0j} +$$

where y_{ij} is the adequate control of diabetic patients, which holds a value of 1 if the individual i of HA j is treated adequately (HbA1c ≤ 7%) and of 0 if it is not. Explicative variables of level 1 are denoted by "x" and those of level 2 by "z". Composed error divides the unexplained component of the dependent variable into 2 parts: one appertaining to the diabetic patient and the other one to the HA. The model assumes components of error (μ and e) with a mean of 0 and constant variance.

Also, intraclass correlation, which is the proportion of the total variance explained by the differences between groups, was calculated. Because the logistic distribution for level 1 residuals holds a variance of $\pi^2/3$ the "score logit" definition of the underlying latent variable[13-14] was applied. Thus, for a 2-level random intercept logistic model and an intercept variance of σ_0^2, intraclass correlation is:

$$\rho_1 = \frac{\sigma_{\mu 0}^2}{\sigma_{\mu 0}^2 + \frac{\pi^2}{3}}$$

The statistical package Stata 8.0.[15] was used for descriptive analysis whereas MlwiN 2.02.[1] was used for the estimation of the multilevel model. The Penalized Quasilikelihood (PQL) method was used for estimation, as it is recommended in order to eliminate bias associated with situations where the number of level 1 units grouped in each level 2 unit is low or when the variance on level 2 is high due to an elevated residual.[6,7,9] Variability excess or defect[6-7] was not assessed for the models estimated in this study because this exceeds its initial objectives.

[c] Geographic area having an EBAIS.

Results

Descriptive analysis

Table 1 presents the general results, including that 49,9% of diabetics in the sample had HbA1c ≤ 7%. Also, 76.6% had a BMI of over 26 (overweight and obesity), and men and people over 60 years of age showed better control results.

The mean population associated to each HA was around 40 000 inhabitants, 22% holding a maximum of secondary school education level. The mean time since the initiation of the reform was 7 years and the mean score on the "Commitment of Management" evaluation was 87%.

As shown in Figure 1, earlier HA s hold a larger number of inadequately controlled diabetic patients and a wider gap between controlled and uncontrolled patients whereas HA s with later conformation show a larger proportion of adequately controlled diabetic patients and a lower gap between these and those not controlled.

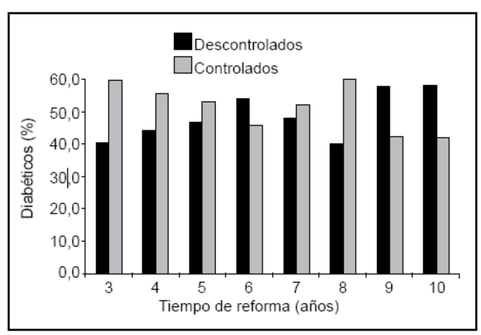

Figure 1. Sample distribution per HA according to time since initiation of reform. Costa Rica, February-March 2004

eje y: Diabetic patients (%)
eje x: Time since reform (years)
leyenda: Uncontrolled / controlled

Figure 2 shows that diabetic patients from HA s of reinforced first level care have mean levels of HbA1c lower than 7%, but with greater variability than that seen for first and second level care HA s.

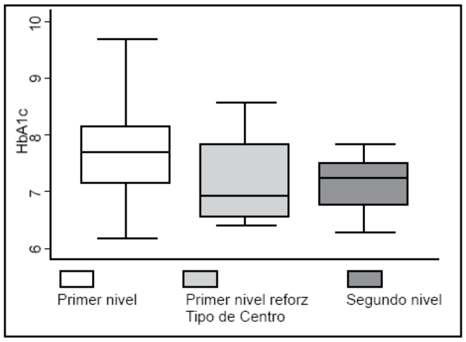

Figure 2. Variability associated to the mean levels of HbA1c per type of HA. Costa Rica, February-March 2004
eje y: HbA1c (%)
eje x: Type of HA : First Level / Reinforced First Level / Second Level

Figure 3 shows that patients from HA s with a later initiation of the reform process have higher HbA1c levels (over 7%) but a lower variability.

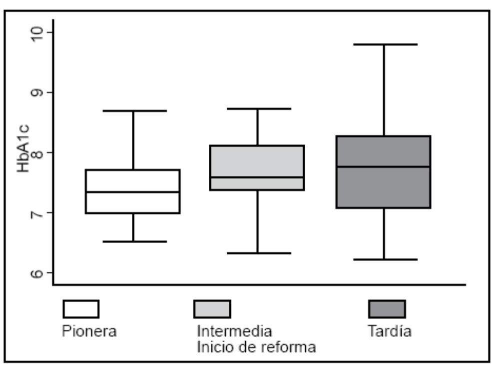

Figure 3. Variability associated with mean HbA1c levels per onset of reform at the HA. Costa Rica, February-March 2004
eje y: HbA1c (%)
eje x: Onset of reform : Pioneer / Intermediate / Late

Table 1. Central tendency measures of selected variables for levels 1 and 2. Costa Rica, 2004

Variable	Mean	Standard deviation	Minimum	Maximum
Dependent variable: glycosylated hemoglobin	**7,59**	**2,09**	**3,10**	**23,9**
Level 1: Individual, n = 3595				
Age	**60,47**	**12,85**	**1,00**	**94,00**
Body Mass Index	**29,74**	**5,35**	**15,8**	**64,00**
Level 2: Group, n = 81 Health Areas				
Time of reform	**7,11**	**2,46**	**3,00**	**10**
Population 2004	**41.212**	**25.308**	**3.985**	**129.424**
Time on Commitment of Management	**5,31**	**1,12**	**3**	**8,00**
Score on Commitment of Management	**0,87**	**0,07**	**0,69**	**0,99**
Children under 6 years of age	**0,12**	**0,02**	**0,08**	**0,17**
Elderly patients	**0,05**	**0,01**	**0,03**	**0,08**
Primary school	**0,67**	**0,14**	**0,33**	**0,89**
Secondary school	**0,22**	**0,06**	**0,09**	**0,34**
University	**0,11**	**0,09**	**0,01**	**0,37**
Distance (km) from hospital	**15,77**	**20,07**	**0,00**	**80,00**
Hours-medic per 1000 inhabitants	**395,96**	**204,11**	**215,34**	**1.437,13**

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Multilevel regression analysis

The main results of the multilevel regression analysis for the random intercept model done on MlwiN are presented. Table 2 shows that masculine gender and older age are associated with a higher probability of achieving control in the diabetic patient. As shown by level 2 variables, diabetic patients from HA s with a later onset of reform have a higher probability of being adequately controlled. Intraclass correlation coefficients were 0,059 and 0,0979 for the void and random intercept models, respectively. This indicates that between 6% and 10% of the variability in the control of diabetic patients is attributable to differences between HA, after controlling for explicative variables.

Table 2. Summary of results from the multilevel logistic regression analysis. Explained variable: Adequate control of the diabetic patient, Costa Rica 2004

Variables	Parameter and standard error	Odds Ratio
Fixed Part *Level 1: Individual,* n = 3500 diabetic patients		
Years of age	**0,02(0,003)***	**1,02**
Woman	**0**	**1**
Man	**-0,18(0,08)****	**0,83**
Nutritional status (BMI)	**0,002(0,007)**	**1,002**
Level 2: Group, n = 81 Health Areas		
Late onset of reform process	**0**	**1**
Intermediate onset of reform process	**-0,65(0,23)***	**0,52**
Pioneer onset of reform process	**-1,11(0,40)***	**0,33**
Score on Commitment of Management	**1,12(0,65)**	**3,07**
Centralized management	**0**	**1**
Decentralized management	**0,55(0,13)***	**1,73**
CCSS-administrated HA	**0**	**1**
Externally hired HA	**-0,31(0,145)****	**0,73**
First level HA	**0**	**1**
Reinforced first level HA	**0,565(0,15)***	**1,76**
Second level HA	**0,75(0,17)***	**2,12**
Percentage of elderly population in HA	**16,58(6,555)****	**15.870.935**
Distance (km) from HA to assigned hospital	**-0,012(0,003)***	**0,99**
Hours-medic per 1000 inhabitants	**-0,001(0,00)***	**0,999**
Random part		
Var (μ_{0j})	**0,36(0,11)**	

Note: data in parenthesis are standard errors, *p<0,01, ** p<0,05

Discussion

The results from the multilevel regression analysis show the lack of a positive impact of the Health System reform of 1995 on the control of the diabetic patient. In fact, HA which had an early onset of this process and that subscribed the Commitment of Management have a lower probability of achieving adequate control of these patients. This is an unexpected result in view of these HA's hypothetical greater experience in the management of the diabetic patients.

Possible explanations for these results include the effects of variables coming from the socio-demographic environment that could influence the outcome of medical care associated to a specific HA and not involve the actual medical practice. Another factor that might account for the results is that the reform process did not start in a random set of HA but was instead initially specifically aimed to those having greater problems and located in the periphery of the country. This unevenness in the start of the process may have a confounding effect over the results of our model.

The present study establishes a significant relationship between age and HbA1c levels, so that higher age associates with a higher probability of having HbA1c ≤ 7%. This may suggest that older diabetic patients develop a greater awareness of the consequences of their disease and also a better compliance to treatment and prevention measures (exercise, diet, etc). The effect of BMI in the control of diabetic patients showed a rather low positive value, perhaps as a consequence of the high prevalence of overweight (40%) and obesity (45%) in the group.

The presence of specialized HA s and the incorporation of specialized medics to the first level of care in the externally hired HA are associated in a positive and significant way with the control of diabetic patients. These results agree with those obtained in a study that found a greater performance in terms of productivity in these HA. [3]

The goodness of fit of the analyzed model shows that there are other variables that are influencing the control of diabetic patients and this should be taken into account in order to identify individual and collective factors that may play a role in this setting. Other variables that could be included in future individual level models are physical activity, type of diet, concomitant diseases, complications, lipid profile data, blood pressure, years of disease evolution, familial functionality,[17-18] compliance to treatment,[19] and metabolic control.[20] Likewise, Level 2 variables that should be considered in further analyses include characteristics of the medical staff taking care of these patients such as years of experience, quantity of weekly consultations and compliance to care regulations.

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