

## Article

# Relationship between Continuity of Care in the Multidisciplinary Treatment of Patients with Diabetes and Their Clinical Results

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Received: 22 November 2018; Accepted: 7 January 2019; Published: 14 January 2019



**Abstract:** Multidisciplinary treatment and continuity of care throughout treatment are important for ensuring metabolic control and avoiding complications in diabetic patients. This study examines the relationship between continuity of care of the treating disciplines and clinical evolution of patients. Data from 1836 adult patients experiencing type 2 diabetes mellitus were analyzed, in a period between 12 and 24 months. Continuity was measured by using four well known indices: Usual Provider Continuity (UPC), Continuity of Care Index (COCI), Herfindahl Index (HI), and Sequential Continuity (SECON). Patients were divided into five segments according to metabolic control: well-controlled, worsened, moderately decompensated, highly decompensated, and improved. Well-controlled patients had higher continuity by physicians according to UPC and HI indices ( $p$ -values 0.029 and  $<0.003$ ), whereas highly decompensated patients had less continuity in HI ( $p$ -value 0.020). Continuity for nurses was similar, with a greater continuity among well-controlled patients ( $p$ -values 0.015 and 0.001 for UPC and HI indices), and less among highly decompensated patients ( $p$ -values 0.004 and  $<0.001$  for UPC and HI indices). Improved patients had greater adherence to the protocol than those who worsened. The SECON index showed no significant differences across the disciplines. This study identified a relationship between physicians and nurse's continuity of care and metabolic control in patients with diabetes, consistent with qualitative findings that highlight the role of nurses in treatment.

**Keywords:** diabetes; continuity of care; multidisciplinary; primary care

## 1. Introduction

The rise in life expectancy in the past 50 years and the subsequent aging of the population has increased the prevalence of chronic diseases [1]. In particular, the prevalence of type 2 Diabetes Mellitus (T2DM) has almost doubled since 1980 [2]. Moreover, persons experiencing this disease frequently present comorbidities and complications [3]. In a scenario where cities are growing and smart cities are emerging, T2DM is a public health problem that highlights the importance of a holistic, scalable, and human-centered view for smart city services [4]. The large amount of information that is available in electronic clinical records (ECR) have made it possible to apply data science with the aim of positively impacting society [5]. Research can therefore focus on concepts such as continuity of care (COC) and multidisciplinary from a data analysis viewpoint, to enable decision-making that may impact a large segment of the affected population.

Continuity of care, understood as the extent to which medical care services are received as a coordinated and uninterrupted succession of events that are consistent with the medical care needs of

patients [6] has been associated with improved clinical results in patients with chronic diseases [7,8]. Research shows a relationship between COC and greater patient satisfaction [9], falling hospitalization rates and emergency department visits [10–13], and a reduction in mortality [8]. In the case of diabetes, continuity is particularly important [14–16], with evidence showing the relationship between low continuity and poor glycated hemoglobin (HbA1c) control, and high continuity and positive control of low-density lipoprotein cholesterol (LDL-C) [17]. Research highlights the importance of incorporating other professionals within T2DM treatment teams [3]. Multidisciplinary teams achieve improved outcomes in HbA1c, plasma glucose, LDL-C, cardiovascular disease risk, microvascular complications, and mortality [18–21]. In primary care, patients with diabetes are mainly treated by multidisciplinary teams, composed usually of a doctor–nurse duo that works with the support of a dietitian and other specialists [22]. The literature shows that collaborative teams for the treatment of diabetes are commonly led by a general practitioner or a family physician, while nurses perform the role of case manager. The nurses' role is particularly important, because, beside maintaining team coordination, they manage the patient treatment schedule, track patient progress, provide counselling to patients, encourage adherence to treatments, promote self-management and preventive care, and make referrals to specialists when required [23,24]. Collaborative teams in diabetes care are based on direct and face-to-face communication between members, and have the distinctive feature of not having a clinical leader, which results in continuous horizontal collaboration [22].

Although previous research highlights the importance of other disciplines, their continuity has not yet been investigated in detail [10,25,26], rather focusing on the continuity of the physician or the team of physicians. However, some patients may be treated mostly by other professionals (e.g., nurses), and lacking continuity even in more sporadic visits (e.g., to dietitians) may be detrimental to treatment. This study aims to understand whether the characteristics of other professionals' continuity have similar characteristics to physicians' continuity.

The continuity of care of physicians and its relationship with clinical outcomes in diabetic patients has been widely studied. Previous research has also emphasized the importance of the participation of nurses and dietitians in the treatment of diabetic patients. However, the COC of these two other disciplines has not been studied in detail. Therefore, the aim of this study was to identify whether there is a relationship between the continuity of these three disciplines (physicians, nurses, and dietitians) and the metabolic control of patients. This work proposes a descriptive analysis of COC provided by medical teams composed of physicians, nurses, and dietitians to patients with diabetes.

## 2. Literature Review

There are more than 30 indices for measuring COC, which can be classified according to five categories: duration, density, dispersion, sequence, and subjective-based [26,27]. Among the non-subjective indices, the most frequently used are the Usual Provider Continuity (UPC) index (also called most frequent provider continuity (MFPC)), which measures the density of appointments with the main provider [28]; the Herfindahl Index (HI) and the Bice–Boxerman Continuity of Care Index (COCI), which both measure dispersion among different providers over a certain period of time [29,30]; and the Sequential Continuity (SECON) index, which uses the sequences of appointments to evaluate the continuity of the provider over consecutive visits [31].

UPC, measured as the percentage of the attention performed by the most frequent provider, is the most frequently used metric for density. One study used this metric to study newly diagnosed cardiovascular patients with conditions such as hypertension, diabetes, and hypercholesterolemia, with the goal of determining their impact on mortality, costs, and health outcomes. Participants with UPC below the median were compared to those with values above the median, using multivariable-adjusted hazard ratios, concluding that lower indices of COC were associated with higher mortality, more frequent cardiovascular events, and higher healthcare costs [32]. A study used both UPC and COCI to compare COC between primary health practices that were using new appointment scheduling methods and those using the existing methods, finding no COC differences between both groups [26].

Another study in general practice with 22 health conditions found that higher COC was associated with fewer admissions for ambulatory care-sensitive conditions, concluding that implementing strategies that improve COC may reduce secondary care costs [25]. These three studies segmented patients according to their COC levels, and conducted statistical analyses to identify differences in outcomes for each group. However, this metric only calculates the density for one provider, without considering other providers that the patient may have seen.

One of the most frequently used metrics for dispersion is COCI. One study of patients with hypertension calculated COCI and analyzed differences in differences (DID), to compare clinical outcomes between patients with high and low COC, finding that a long-term physician–patient relationship may improve their health-related quality of life [33].

Several studies have used two or more metrics to evaluate COC, considering density, dispersion, and sequence [11,34–38]. For instance, a study on patients with multiple chronic conditions, including diabetes, used UPC, COCI, and SECON to propose an integrated COC index (ICOC) using principal component analysis. This study analyzed COC at the physician and medical facility levels, and found that a higher COC was related to lower emergency room use and lower hospitalization rates, also finding that the combined COC index was more stable than each metric considered separately [35]. Another study used UPC, COCI, and SECON to analyze the relationship between COC and emergency service use, finding a negative relationship between COC and use of emergency services [36].

Regarding patients with diabetes, low levels of COC have been found to be associated with poor HbA1c control [17] and a higher risk of end-stage renal disease and hospitalization [13], while high levels of COC were associated with good LDL control [17], lower costs (considering diabetes-related hospitalization and emergency visits) [39] and lower odds of being admitted to the hospital [40]. Some studies have found no association between COC and HbA1c, lipid, or eye exam frequency [41].

Only one of the reviewed studies considers a second discipline of healthcare professionals beyond physicians, comparing the COC of physicians with the COC of a nurse–physician team [26]. Other studies mention the importance of other disciplines but do not calculate COC for them [10,25]. None of the reviewed studies have evaluated COC separately for the other disciplines involved.

### 3. Research Methodology

The reviewed research studying the relation between COC and clinical outcomes in patients with diabetes, shows that although all disciplines participating in the treatment of T2DM are important, COC has only been studied in depth for physicians. Furthermore, the specific features of the setting of the present study, which includes a high turnover of physicians in the healthcare centers, could affect the characteristics of COC for physicians. These issues generate the following research questions:

- Does a scenario with high turnover of physicians in primary care affect the positive relation between continuity of care and patient outcomes described in the literature?
- Is it possible to find an association between COC for the other disciplines involved in the treatment of diabetes (nurse and dietitian), and patient evolution?

To answer these questions, we analyzed data regarding appointment scheduling and HbA1c test results captured by information systems in three primary healthcare centers. We calculated COC using the most frequently used metrics available in the literature (UPC, HI, COCI, SECON) for the three involved disciplines, separately (physicians, nurses and dietitians). As clinical outcome, we used patient evolution, described as a categorical variable (stable, improved, worsened, moderately decompensated, and highly decompensated). We compared whether there were statistically significant differences in COC for the different patient evolution segments.

This section describes the research methodology used in this study in detail. First, we describe the setting of the study, followed by the patients that were selected for it. Then, we describe how the patient evolution segments were determined, the continuity metrics that we used, the descriptive variables of the population, and the statistical methods employed.

### 3.1. Settings

The Chilean Ministry of Health establishes a treatment protocol for chronic conditions such as T2DM, published as a clinical guideline (e.g., T2DM Guideline [42]). The treatment of patients with diabetes in Chile is in accordance with these guidelines [42], which establish the frequency by which appointments, laboratory tests, and pharmacological treatment should be undertaken, according to HbA1c measurements. They divide patients into three categories: stable (patients with HbA1c lower than 7%); moderately decompensated (patients with HbA1c between 7% and 9%); highly decompensated (HbA1c greater than 9%). While treatment is ultimately determined by the treating professionals, the guidelines are expected to form the basis for treatment.

This research was conducted in three university-affiliated primary healthcare centers located in low-income districts with high social vulnerability in Santiago, Chile. These centers provide health-related services to an average of 8000 persons per year, more than 30% of which experience T2DM. Two practices operate within each center, each one with its own multidisciplinary team composed of general practitioners (GP), family physicians (FP), nurses, dietitians, and psychologists, among others. One notable characteristic of these centers is their very high turnover rate of physicians [43]. This is due to the way in which physicians are trained in Chile, whereby professionals who have recently graduated as GPs begin their work experience in these centers. Within one to two years, GPs generally begin their specialist studies, leaving the primary healthcare environment.

The care that is delivered by the treatment team consists of cardiovascular periodic appointments (CVPA) that can be carried out by any of the three disciplines that make up the team. In the CVPA, the physical condition of the patient is evaluated, previously requested exams are reviewed, and the risk of cardiovascular diseases is evaluated. Patients with HbA1c results lower than 7% should be seen every three months, and patients with HbA1c over 7% should be seen on a monthly basis, alternating the visited disciplines. Patients must have at least one annual diabetic foot evaluation appointment. Patients with HbA1c results over 9% should also participate in workshops about insulin. All professionals have access to the electronic clinical records of the patients, as well as having direct interactions among them, which is facilitated by their being co-located.

### 3.2. Subjects

The patients in this study were chosen from the healthcare center information records, in particular, the appointments schedule and laboratory results, between 2012 and 2016. Only individuals diagnosed with T2DM were selected, and only appointments marked as CVPA with either GPs or FPs, nurses, and dietitian were selected.

For analysis purposes, we consider as inclusion criteria that the patient has had at least 12 months of treatment in the centers, in which time each individual was subject to at least two HbA1c tests, in order to establish evolution. The time of analysis was bounded to a maximum of 24 months, similar to timeframes utilized in previous research [10,17,37]. Most of the patients had been receiving care for a longer period of time. For those cases, we only considered the most recent 24-month period. As exclusion criteria, adherence to medical appointments was used. Only patients with acceptable adherence, established as four months beyond the expected date of appointment [18], were used.

To analyze the results, we divided patients by evolution of their HbA1c measurements. To do so, we used definitions similar to those utilized in a previous study: Three segments of patients who could be categorized as belonging to a particular treatment segment (stable, moderately decompensated, and highly decompensated), and another segment with positive evolution [44]. The higher number of patients in our study allowed us to identify a fifth category: patients with a negative evolution. Accordingly, the segments were defined as follows:

Improved: patients with an initial HbA1c equal to or greater than 7%, and a final score lower than 7%, or with an initial HbA1c that was equal to or greater than 9%, and a final score of lower than 9%. In cases with more than two measurements, only those in which their linear regression had a negative slope were included.

Worsened: patients with an initial HbA1c lower than 7% and a final score equal to or greater than this value. In cases with more than two measurements, only those in which their linear regression had a positive slope were included.

Stable: patients with an average HbA1c of lower than 7%, at most one score greater than this value but lower than 9%, and who did not belong to any of the aforementioned groups.

Moderately decompensated: patients with all their HbA1c results lower than 9%, and who do not belong to any of the aforementioned groups.

Highly decompensated: patients with at least one result over 9%, and who do not belong to the improved group.

### 3.3. Continuity Metrics

To measure COC, we used four metrics that have been used in several previous COC-related studies, in regard to diabetic patients as well as other chronic diseases: COCI [30], HI [29], UPC [28], and SECON [31]. These four metrics were applied to each discipline separately. All of these indices produced values of between 0 and 1, where 1 corresponds to the case in which all appointments were provided by the same professional. Table 1 outlines the formulas used to calculate the indices.

**Table 1.** Formulas for computing the continuity of care indices used in the study.

Metric	Formula	Continuity Aspect Measured
Bice–Boxerman Continuity of Care Index (COCI)	$\frac{(\sum_{i=1}^P n_i^2) - N}{N(N-1)}$	Dispersion of appointments among the different professionals
Herfindahl Index (HI)	$\sum_{i=1}^P \left(\frac{n_i}{N}\right)^2$	Dispersion of appointments among the different professionals
Usual Provider of Care (UPC) Index	$\max_i \frac{n_i}{N}$	Concentration of appointments in a main professional
Sequential Continuity of Care (SECON) Index	$\frac{(\sum_{j=1}^{N-1} c_j)}{N-1}$ where $c_j = \begin{cases} 0 & \text{if } p_{j-1} = p_j \\ 1 & \text{if no} \end{cases}$	Patient handoff among professionals

The variable  $n_i$  corresponds to the appointments of professional  $i$ ,  $N$  to the total patient appointments,  $P$  to the total number of treating professionals, and  $p_j$  to the provider of the  $j$ -th appointment.

The indices for the three disciplines relevant to this study were calculated separately, to understand how the types of care provided by each professional discipline related to patient evolution. For reference purposes, the Number of Providers (NOP) indicator was also considered for each discipline [45]. This index can be used as a dispersion measurement, although it is not sensitive to changes in the appointment distribution among providers, or to the differences in the total number of appointments of each patient.

The results of the measured indices can be interpreted as having high continuity if they are greater than 0.75 (75% of appointments provided by the same professional), a medium continuity for values between 0.30 and 0.74, and a low continuity for values less than 0.3 [46].

### 3.4. Descriptive Variables of the Population

The following population variables were taken into account: age; time spent living with diabetes; Chronic Illness with Complexity (CIC) index [47]; Diabetes Complications Severity Index (DCSI) [48]; sex; the medical practice where the appointment was undertaken.

The DCSI and CIC indices describe the level of severity and complexity of the patient, based on the presence of certain diseases that are relevant in the context of diabetes. The DCSI reflects the severity of the complications that are associated with diabetes, considering diagnoses belonging to the following seven categories: cardiovascular complications, nephropathy, retinopathy, peripheral vascular disease,



cerebrovascular accident, neuropathy and metabolic disorders. The value of the index is the sum of the scores assigned to each category (without abnormality = 0, some abnormality = 1, or severe abnormality = 2). Exceptionally, the neuropathy can only have a score of 0 or 1. Therefore, the severity index reaches values between 0 (without abnormalities in any category) and 13 (in the case of severe abnormalities in all categories) [47,49]. On the other hand, CIC measures the number of pathologies that the patient presents that are not related to diabetes, but that can also impact on their health condition. It considers the presence of diseases that are grouped into six categories: gastrointestinal, skeletal muscle, lung, cancer, substance abuse, and mental illness. The index is calculated as the sum of the scores that are assigned to each category (0 = none of the diseases considered in the category is presented, 1 = one or more diseases belonging to the category are presented). Then, the comorbidity index reaches values between 0 (no disease on the list) and 6 (at least one disease for each category specified) [48,49].

### 3.5. Statistical Analysis

Descriptive variables of the population were assessed for normality, using a Shapiro–Wilk test. For variables with normal distributions, the mean and standard deviation are presented. For variables that were not normally distributed, the median, minimum and maximum values are presented. The dependence of patient segmentation with each descriptive variable was evaluated with a two-tailed chi-squared test.

In the case of continuity metrics, the values of each metric are bounded to a (0, 1) interval, so that they are not normal by construction. However, as our objective was to verify if there is a relationship between each of those indices and the patient's evolution, we used a two-tailed Student's *t*-test to evaluate differences between the mean of each segment and the mean of the complete population. This analysis is possible because, in big samples with finite variance, we can assume that the mean is distributed approximately as a normal by the central limit theorem. Similar studies have used statistical tests of mean differences to assess the relationship between continuity and clinical results [13,17,38,49].

The results of the continuity metrics are presented using the mean and the median. The minimum and maximum values are not presented since in each segment we found values 0 and 1 (limits of the metric).

Statistical significance was determined with *p*-value lower than 0.05. Analyses were performed using the R software (<https://www.r-project.org/>).

### 3.6. Research Ethics

The research protocol of the study was approved by the Scientific Ethics Committee of Pontificia Universidad Católica de Chile, project ID 13-347, and ratified by the corresponding Scientific Ethics Committee from the Chilean Ministry of Health. An Informed Consent dispense was approved by both committees, because it had no direct impact in the treatment of patients and data was anonymized previous to our analysis.

## 4. Results

Out of a total of 3369 patients, 1836 met the inclusion criteria and were divided into the five defined segments. 60% of all patients were women, with a lower proportion in the worsened segment (50%) and higher in the highly decompensated segment (67%). The average age was 61 (SD = 11.5), and the average number of years with which patients had lived with diabetes was 4.4 (SD = 3.4). The CIC index scored an average of 1.30 (SD = 1.10), while the DCSI scored an average of 0.91 (SD = 1.37). Table 2 outlines the descriptive variable values, and the *p*-value of the statistical test of independence between these values and the five defined patient segments.

**Table 2.** Characterization of patients by segments and the total population of the study.

	Stable	Improved	Moderately Decompensated	Worsened	Highly Decompensated	Total Population	$\chi^2$ <i>p</i> -Value between Segments	Normality Test <i>p</i> -Value
Total (N (%))	655 (36%)	325 (18%)	247 (13%)	221 (12%)	388 (21%)	1836 (100%)		
Gender (N (%))							<0.001	
Male	246 (38%)	142 (64%)	104 (42%)	110 (28%)	129 (40%)	731 (40%)		
Women	409 (62%)	183 (56%)	143 (58%)	111 (50%)	259 (67%)	1105 (60%)		
Age (mean (SD))	63.1 (11.7)	61.0 (11.3)	63.1 (10.6)	59.4 (11.8)	58.4 (11.1)	61.3 (11.5)	0.519	0.025
Years w/T2DM (med (min, max))	2.8 (0.0, 16.9)	5.2 (0.0, 24.9)	5.4 (0.0, 20.5)	3.5 (0.0, 17.4)	5.6 (0.0, 23.0)	4.6 (0.0, 24.9)	0.331	<0.001
CIC (med (min, max))	1 (0, 5)	1 (0, 5)	1 (0, 5)	1 (0, 4)	1 (0, 5)	1 (0, 5)	0.181	<0.001
DCSI (med (min, max))	0 (0, 8)	0 (0, 7)	0 (0, 7)	0 (0, 7)	0 (0, 8)	0 (0, 8)	0.018	<0.001
HbA1c (med (min, max))								
First	6.2 (4.5, 6.9)	9.1 (7.0, 16.1)	7.6 (6.2, 8.9)	6.5 (4.7, 6.9)	8.9 (4.2, 16.4)	6.9 (4.2, 16.4)	<0.001	<0.001
Last	6.1 (4.7, 6.9)	6.8 (4.5, 8.9)	7.5 (5.7, 8.8)	7.5 (7.0, 17.4)	9.7 (5.1, 15.3)	7 (4.5, 17.4)	<0.001	<0.001

T2DM: Type 2 Diabetes Mellitus. CIC: Chronic Illness with Complexity index. DCSI: Diabetes Complications Severity Index. A  $\chi^2$  test was used to assess the dependence between each variable and the segmentation, obtaining the result that only DCSI is dependent on the evolution. A Shapiro–Wilk test for normality was also applied to the variables. Normal variables are described with mean and standard deviation, and non-normal variables are described with median value (med), accompanied by the minimum (min) and maximum (max) values. Statistical significance was established as *p*-value < 0.05.

Table 3 shows the number of total appointments and appointments by discipline for the five patient segments. The number of appointments of physicians and nurses had values that were below average in the stable and worsened segments, and above average in the other segments. This was consistent with the difference in the appointment frequency as outlined in the treatment guidelines. Conversely, in the case of the dietitians, it can be seen that the value was significantly lower only among patients from the worsened segment. By comparing the patients who remained stable with those who were stable but subsequently worsened, the only significant differences appear in appointments with the dietitian, with more appointments ( $p$ -value = 0.01) and more professionals ( $p$ -value < 0.01) than stable patients. All of these differences are captured by the continuity metrics, thereby enabling comparisons to be made between patients.

**Table 3.** Patients and visits for each discipline by segments and total population.

VISITS	Stable	Improved	Moderately Decompensated	Worsened	Highly Decompensated	Total Population
Patients (n (%))	655 (36%)	325 (18%)	247 (13%)	221 (12%)	388 (21%)	1836 (100%)
Total visits (mean (med))	5.61 (5) *	9.30 (7) *	7.76 (7)	5.98 (5) *	10.48 (8) *	7.63 (6)
Physician visits (mean (med))	2.93 (3) *	3.94 (4) *	3.77 (4)	3.11 (4) *	4.27 (4) *	3.53 (3)
Nurse visits (mean (med))	1.89 (2) *	4.46 (2) *	3.14 (2)	2.29 (2) *	5.36 (3) *	3.30 (2)
Dietitian visits (mean (med))	0.80 (0)	0.90 (1)	0.85 (0)	0.58 (0) *	0.85 (1)	0.81 (0)

med: median. We applied a Shapiro–Wilk test for normality for each variable, obtaining that none were normally distributed ( $p$ -value < 0.001). Due to the large size of the sample, we applied a  $t$ -student test for comparing the mean of each segment with the mean of the total population. Statistically significant differences ( $p$ -value < 0.05) are marked with \*.

Table 4 shows that Physician COC achieved a higher score in the case of stable patients, according to the indices of UPC concentration ( $p$ -value = 0.03) and HI dispersion ( $p$ -value < 0.01), while highly decompensated patients showed a significantly lower continuity in the HI ( $p$ -value = 0.02). In the case of nurses, the behavior of the COC indices was similar, with the UPC and HI indicators generating higher scores among stable patients ( $p$ -value = 0.01 and < 0.01), and lower scores among highly decompensated patients ( $p$ -value < 0.01 in both indicators). In addition, the HI was significantly lower in the case of improved patients. The COC for dietitians showed no significant differences among the moderately decompensated segment, with lower continuity in the COCI, UPC, and HI indices ( $p$ -values = 0.08, 0.08 and 0.07, respectively). However, the major difference in this segment was the adherence to treatment with the dietitian, with a lower participation of patients who worsened, but greater among those who improved ( $p$ -value < 0.01). The SECON index showed no significant differences in any of the three disciplines.



**Table 4.** Continuity of care indices for segments and total population.

COC METRICS	Stable	Improved	Moderately Decompensated	Worsened	Highly Decompensated	Total Population
<b>Physician</b>						
Patients (n (%))	631 (96%)	319 (98%)	239 (97%)	208 (94%)	371 (96%)	1768 (96%)
NOP (mean (med))	2.48 (2) *	2.92 (3)	2.97 (3) *	2.64 (3)	3.16 (3) *	2.79 (3)
COCI (mean (med))	0.30 (0.10)	0.27 (0.11)	0.26 (0.11)	0.30 (0.10)	0.28 (0.13)	0.29 (0.10)
UPC (mean (med))	0.57 (0.50) *	0.53 (0.50)	0.52 (0.50)	0.56 (0.50)	0.52 (0.50)	0.55 (0.50)
HI (mean (med))	0.54 (0.50) *	0.48 (0.38)	0.47 (0.38)	0.52 (0.41)	0.46 (0.38) *	0.50 (0.40)
SECON (mean (med))	0.33 (0.00)	0.34 (0.25)	0.31 (0.20)	0.33 (0.17)	0.35 (0.25)	0.33 (0.20)
<b>Nurse</b>						
Patients (n (%))	572 (87%)	289 (89%)	222 (90%)	189 (86%)	354 (91%)	1626 (89%)
NOP (mean (med))	1.79 (2) *	2.42 (2) *	2.15 (2)	1.89 (2) *	2.65 (2) *	2.15 (2)
COCI (mean (med))	0.50 (0.33)	0.45 (0.33)	0.48 (0.33)	0.50 (0.33)	0.43 (0.32)	0.47 (0.33)
UPC (mean (med))	0.72 (0.67) *	0.66 (0.57)	0.68 (0.67)	0.72 (0.67)	0.64 (0.55) *	0.69 (0.67)
HI (mean (med))	0.70 (0.56) *	0.61 (0.50) *	0.65 (0.56)	0.69 (0.56)	0.58 (0.50) *	0.65 (0.50)
SECON (mean (med))	0.51 (0.50)	0.51 (0.50)	0.52 (0.50)	0.52 (0.50)	0.48 (0.48)	0.50 (0.50)
<b>Dietitian</b>						
Patients (n (%))	319 (49%)	182 (56%)	118 (48%)	86 (39%)	200 (52%)	905 (49%) *
NOP (mean (med))	1.25 (1)	1.21 (1)	1.31 (1)	1.21 (1)	1.21 (1)	1.24 (1)
COCI (mean (med))	0.79 (1.00)	0.82 (1.00)	0.74 (1.00)	0.81 (1.00)	0.84 (1.00)	0.80 (1.00)
UPC (mean (med))	0.89 (1.00)	0.91 (1.00)	0.87 (1.00)	0.90 (1.00)	0.92 (1.00)	0.90 (1.00)
HI (mean (med))	0.89 (1.00)	0.90 (1.00)	0.85 (1.00)	0.90 (1.00)	0.91 (1.00)	0.89 (1.00)
SECON (mean (med))	0.80 (1.00)	0.84 (1.00)	0.76 (1.00)	0.81 (1.00)	0.86 (1.00)	0.82 (1.00)

NOP: Number of Providers, COCI: Continuity of Care Index, UPC: Usual Provider of Care, HI: Herfindahl Index, SECON: Sequential Continuity, med: median. Metrics are not normal by construction (they are bounded between 0 and 1). The minimum and maximum values for all metrics are 0 and 1, respectively. We applied a Shapiro–Wilk test for normality for each variable, obtaining that none were normally distributed ( $p$ -value < 0.001). Due to the large size of the sample, we applied a t-student test for comparing the mean of each segment with the mean of the total population. Statistically significant differences ( $p$ -value < 0.05) are marked with \*. For each discipline, metrics were computed only for patients with at least one visit to a provider from this discipline.

## 5. Discussion

Approximately 75.2% of the Chilean population is insured by the public health care system, which is funded by a 7% mandatory deduction from salaries. An insured person may provide a fixed copay to be able to select their preferred healthcare provider, or they may be treated at a predetermined facility, which provides free services to the lowest income population (18.1% of the overall population) [50]. For them, primary healthcare is provided at centers called Centros de Salud Familiar (Family Health Centers, or CESFAM). CESFAM treat acute morbidities that may be solved or referred to a more complex center, and chronic morbidities that require periodic assessment, e.g., diabetes, hypertension, and chronic pulmonary disease. This study analyzed data pertaining to three university-affiliated CESFAM centers.

One of the main issues faced by the public Chilean healthcare system is a lack of physicians: particularly in the CESFAM, there is a lack of GP and FP. In Chile, the average number of patients per physician in primary care is 920, whereas the average in the private sector is 276, and in member states of the Organization for Economic Co-operation and Development (OECD), it is 294 [51,52]. Regardless, in metrics such as mortality amenable to health care, Chile has been found to have rates comparable to the OECD [53]. Another relevant shortcoming of the primary healthcare system in Chile is the high turnover of healthcare professionals, particularly of physicians, due to the statutes that establish their working conditions. This reduces the system effectiveness and impacts on the quality of care [44].

This study used a sample of 1836 patients, with similar demographic characteristics to previous studies [17,39]. The results show two variables with differences among the segments: the DCSI score and gender. However, no correlation was found between DCSI and the metrics used to measure COC, or between any of the indices and the gender of the patients.

In this descriptive analysis, we did not propose an intervention—rather, we studied the data captured by the information systems while the healthcare professionals were using guidelines and protocols that should have been applied in every case. Considering this, we sought to understand whether the care provided by the centers varied in patients with different clinical outcomes.

Continuity of care has been extensively studied in previous research, particularly for physicians or multi-providers of care [9,13,25], but the particular characteristics of primary care in Chile (few physicians, with high turnover), which are also present in other countries, may impact the characteristics of continuity [54]. However, previous research had not focused on the continuity of care for dietitians and nurses, which are two essential roles for the treatment of diabetes. Our results show that, as expected from previous research, physician continuity of care is related to patient evolution, and that nurse continuity of care has a similar relevance.

Physicians had a greater COC when treating patients from the stable segment, and a lower continuity for highly decompensated patients, with the latter also having appointments with the largest number of different professionals. Due to the high turnover of physicians in the centers, it is possible that patients who require more frequent visits encounter difficulties in reserving appointments with the same professional, therefore impacting COC. These results are consistent with findings from previous studies, in which more appointments and a greater number of different physicians have been associated with lower COC [55].

The results showed the same tendency regarding nurses, albeit with higher COC values, which reflects a lower turnover of nursing staff compared to physicians. Noticeably, the stable and worsened segments were very similar. This could be due to the fact that both groups of patients begin the period with treatment similar to that outlined in the guidelines, which only varies when patients who worsen begin to show HbA1c results that are greater than 7%. These results suggest that the continuity of the nurse is as important as that of the physician for diabetic patients, which is consistent with the provisions that are outlined in national and international guidelines, as well as in multiple studies [3,42]. Previous research in this area was qualitative or based on self-reported information, in contrast to our findings in which the metrics were calculated according to data extracted from an information system.

By comparing our results with previous studies, we see that values of the UPC index are similar to the results of previous studies in the case of physicians [36], but they are significantly higher for nurses. The same studies have identified a relationship between lower continuity and the rate of emergency services utilization. The relationship between COC and blood pressure in diabetic patients and those with cardiovascular diseases has also been studied previously, without identifying a significant relationship between BP control and personal continuity after adjustment for the total number of visits [56].

It should be noted that not only the participation or continuity of care of nurses in the treatment is relevant, but also their level of specialization. The role of the Nurse Practitioner performed by the nurses of the centers is based on a model that is characterized by its holistic, quality, preventive, and health promotion, for which nurses take certain tasks of physicians. This is important because, when we say that the continuity of nurses is important, we are referring to nurses who have a more advanced and preponderant role in the treatment of the patient and that can replace part of the physicians' functions. Proving that the continuity of nurses is as relevant as that of the physicians validates this role and the existing collaboration within the work team [24,44].

Continuity among dietitians is somewhat different, since the indices show no major discrepancies between the segments but do demonstrate variations in terms of adherence to the protocol. According to the guidelines, all patients should visit the dietitian with the same frequency as a physician or nurse. However, during the period of analysis, approximately 50% of the patients failed to visit the dietitian, with the greatest adherence being in the improved patient segment, and the least in the worsened segment. Previous studies have presented quantitative evidence on the link between the participation of a dietitian within a clinical team, which is to ensure the provision of balanced treatment among the three professionals of a care team, and a positive evolution in HbA1c levels [18]. We should consider the possibility that patients with a lower adherence to dietitian appointments could also have a lower adherence to medication or a recommended behavior that could explain the differences. Future studies will need to analyze the causality of this relationship in greater detail.

Regarding the general context, Chile is a high-income country according to The World Bank data, as are the countries of the studies reviewed in this discussion [57]. The income level of the country has been associated with diabetes prevalence and diabetes-related complication risk [2,3]. This condition, in addition to the demographic characteristics of the population, allows us to compare our results with previous literature. However, in our particular setting, patients belong to the lowest income population, which may be related to a higher risk of diabetes-related complications [58]. Because of that, even when relative differences presented in each work are comparable with our results, one should be cautious with absolute comparisons between metrics.

Among the strengths of our study is the size of the population, which is comparable with the sample size in related work, and the fact that medical decisions are based on a protocol based on HbA1c test results, which allows for the comparison of patients with similar evolutions, assuming similar treatments. At the same time, the fact that a common protocol is being followed can also be considered as a weakness of this study, because patients are treated under particular conditions that might limit the universality of the results. Another limitation of this study is that it only considered HbA1c measurements as an outcome with which to segment the patients. More thorough analysis should consider other variables, e.g., blood pressure, cholesterol, weight, BMI, which were not available for our study. Also, we considered the last 12–24 months of data for each patient, without considering the time of diagnosis. Although most patients had already been under treatment for some time, some patients might have been recently diagnosed, and healthcare professionals might be willing to try different courses of action with patients who had been previously unsuccessful, even if the guidelines and health programs establish similar actions for all patients, according to the last HbA1c test result.

Our results show that, as expected from previous research, physician continuity of care is related to patient evolution, but also that nurse continuity of care has a similar relevance. Even though dietitians are too few to evaluate the impact of their continuity, patients who adhere to nutritional treatment have better outcomes. These results may help healthcare centers with little resources and high physician turnover to focus their protocols and guidelines towards maintaining nurse continuity and improving adherence to nutritional treatment.

## 6. Conclusions

Our study shows that there is an association between the continuity of care that is provided by physicians and nurses, and the evolution of diabetic patients, as well as a relationship between dietitian visit adherence and evolution. Those results are interesting, particularly for nurses and dietitians, for whom there are not enough previous quantitative studies. The applied methodology allows to conclude that variables are related, but we cannot evaluate causality of the results. Further studies should focus on a specific intervention to assess causality.

Primary healthcare centers with little resources and high physician turnover, in line with the development of smart city services, and aiming to maintain patient-centered policies, may focus their protocols and guidelines towards maintaining nurse continuity and increasing their adherence to nutritional treatment.

**Author Contributions:** C.S.-P. was the main researcher who collected data, applied methods, and analyzed results. M.S. and V.H. jointly provided guidance and substantial revisions to the manuscript. F.P. provided clinical analysis and contributed in the discussions. All authors have agreed on the final manuscript.

**Funding:** This paper was partially funded by CONICYT-PCHA/Doctorado Nacional/2016-21161705 and CONICYT-FONDECYT/1181162 (Chile). The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

**Acknowledgments:** We would like to thank Áncora UC primary healthcare centers for their help with this research.

**Conflicts of Interest:** The authors declare no conflict of interest.

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