

Article

Prevalence and Predictors of Type 2 Diabetes Remission in a Multidisciplinary Primary Care Program for Patients with Poor Glycemic Control: Role of Weight Change in a Low-Income Mexican Population

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Abstract

Background/Objectives: Type 2 diabetes (T2D) remission can be defined as a return to a HbA1c < 6.5% (<48 mmol/mol) sustained without ongoing treatment for at least 3 months. Prevalence estimates and factors associated remain unknown for LMIC and resource-limited settings. **Methods:** We conducted a retrospective observational analysis of electronic medical records from 8463 adults who received multidisciplinary care at Mexico's primary care specialized units (UNEMES-EC) between 2015 and 2019 and who were referred for inadequate metabolic control. Remission was defined per 2021 ADA criteria as HbA1c < 6.5% sustained for ≥ 3 months without glucose-lowering medications. After estimating the prevalence of T2D remission, logistic regression models were used to evaluate its sociodemographic and clinical predictors, with particular attention to weight change and baseline adiposity interactions. **Results:** RT2D prevalence was 0.87% (95% CI: 0.68–1.10) over a median 393-day follow-up. Weight loss $\geq 10\%$ (adjusted OR 2.75; 95% CI: 1.21–6.27) and systolic blood pressure (tertile 3 vs tertile 1: OR 2.49; 95% CI: 1.17–5.26) were positively associated with RT2D, while elevated baseline HbA1c (tertile 3 vs. tertile 1: OR 0.09; 95% CI: 0.02–0.33), triglyceride levels (tertile 3 vs. tertile 1: OR 0.49; 95% CI: 0.24–0.98) and intensive pharmacotherapy were inversely associated with RT2D. No associations with HDL and total cholesterol were found. Age, sex, educational attainment, and income demonstrated no independent associations with remission. Among lifestyle-treated patients achieving $\geq 5\%$ weight loss, remission prevalence reached approximately 11%. No significant interaction between baseline BMI and weight change was detected ($p = 0.60$). **Conclusions:** This first large-scale Mexican study establishes RT2D as an achievable endpoint in patients with poor baseline metabolic control. The findings suggest that remission could be achieved with equity-focused, weight-centered interventions even in resource-constrained health systems and populations.



Academic Editor: Bogdan Timar

Received: 16 April 2026

Revised: 30 May 2026

Accepted: 10 June 2026

Published: 25 June 2026

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Keywords: diabetes remission; weight change; BMI; prevalence; multidisciplinary healthcare; type 2 diabetes; Mexico; primary care

1. Introduction

In people with type 2 diabetes (T2D), remission (RT2D) is characterized by sustained restoration of normoglycemia without pharmacological therapy. In 2021, the American Diabetes Association (ADA) updated its RT2D criteria with an operational definition based only on one biomarker of glycemic control, HbA1c < 6.5%, and a sustained period of at least three months in the absence of glucose-lowering therapies [1]. Although bariatric surgery had historically been regarded as the sole pathway to RT2D [2,3], physiological studies have identified some mechanisms of diet-induced remission [4,5]. Translating these mechanistic insights to primary care settings has proven feasible [6–8]. Collectively, these findings position RT2D as a realistic therapeutic target within routine clinical practice.

In addition, the incidence or prevalence of RT2D in health services has been documented even when remission was not a clinical objective. In the United States and Hong Kong, an incidence of 2.8 and 7.8 cases of RT2D per 1000 person-years has been reported in private healthcare services [9,10]. Scotland and Korea have documented RT2D prevalences of 4.8% and 6.8%, respectively, in public health systems [11,12]. These figures have been estimated mostly in insured populations and, despite their variation, confirm that remission can occur even in the absence of clinical protocols designed to promote it.

Several important clinical predictors of RT2D have been identified that could guide the targeting of RT2D programs in primary care settings. Having a recent diagnosis of T2D (less than 8 years), lower baseline HbA1c, and being prescribed fewer oral hypoglycemic agents have been associated positively with RT2D in both observational and experimental studies [9,10,13]. High blood pressure has been moderately associated with RT2D in some trials, but not in early epidemiological studies [9,13,14]. BMI appears to be a predictor, but its association does not appear to follow a linear pattern [13,14]. Evidence on socioeconomic factors as predictors of RT2D is scarce. Older age has been a moderate but positive predictor of RT2D in some studies [9,14], but not in others [13,15], and little is known about education and income. Most observational studies have been conducted in insured populations with social security and/or patients with relatively controlled T2D. Little is known about predictors of RT2D in metabolically uncontrolled patients and in resource-limited settings, such as most Latin American populations.

Among modifiable factors, weight loss has shown the strongest and most consistent dose-response relationship with RT2D. This relationship has been studied both experimentally and observationally. In the DiRECT clinical trial, 48% of participants achieved RT2D, with an average weight loss of 10 kg [6]. Similarly, in the Look AHEAD trial that promoted a 10% weight loss, the prevalence of RT2D was 11.5% in the first year [13]. In observational studies, the weight threshold associated with RT2D has varied: while some place it at ≥ 5 kg [11], others suggest that only ≥ 10 kg losses promote RT2D, after adjusting for disease duration [15,16].

The magnitude of weight loss required to achieve RT2D varies depending on individual characteristics such as ethnicity and BMI. Physiologically, there is a level of personal adiposity that triggers or reverses T2D, correlated with the level of obesity [17]. In addition, epidemiological observations suggest that there are ethnic variations. For example, a study in the Japanese population found an association between loss of $\geq 5\%$ of body weight and remission, but only in people with BMI ≥ 25 kg/m². Those with lower BMI did not show the same relationship, despite losing weight [18]. In another study with an Asian population and recent cases of T2D diagnosis, RT2D was associated even with a weight loss of less than 5% [10]. These findings suggest that the average magnitude of weight loss required to achieve RT2D in the Mexican population could vary according to BMI levels, as observed in other ethnic groups.

In México, people without social security and without employment-based health-care are eligible to use the national public primary care system. Nationwide, there are 101 Medical Specialty Clinics for Chronic Diseases (UNEMES-EC) that provide an intensive follow-up model for 12 months through a team of doctors, nurses, nutritionists, psychologists, and social workers. UNEMES-EC patients are referred from general primary care clinics when they are unable to achieve clinical control of at least one chronic disease: diabetes, hypertension, dyslipidemia, or obesity [19]. This population is characterized by lower socioeconomic status and poorer metabolic control than the general population. Given this profile, they are less likely to have the capability, knowledge, and opportunities to manage T2D.

This study aimed to estimate the prevalence of RT2D, examine its association with weight change, and identify its clinical and sociodemographic predictors, in a socially vulnerable Mexican population receiving diabetes care within a multidisciplinary care model.

2. Materials and Methods

2.1. Analysis Design

This study is a retrospective observational analysis based on electronic medical records (EMR) from UNEMES-EC. The clinical protocol provides oral hypoglycemic drugs, insulin, and lifestyle changes, and it explicitly promotes a weight loss of at least 5% over a 12-month period. It does not and did not consider RT2D a clinical target.

This manuscript is derived from quality assessment activities carried out on a regular basis by the National Center for Preventive Programs and Disease Control (CENAPRECE), whose first objective was the practice of public health. Because it is carried out outside a research context, no research protocols are registered for this purpose [20]. Data were collected and stored in an EMR system in compliance with Mexican regulations on data protection. The analysis employed de-identified datasets.

The analysis included only EMR of patients who started care between 2015 and 2019. Individuals with a registered diagnosis of T2D, aged 18 years or older, with baseline clinical indicators, who completed the program and had HbA1c, weight, and pharmacological treatment records at the end of the 12-month period were included in the analysis.

2.2. Outcome Variable

The primary outcome was the prevalence of RT2D at the end of the follow-up period (approximately 12 months). To define remission, the criteria established by the ADA [1] were employed, operationalized as: (1) a period of normoglycemia ($\text{HbA1c} < 6.5\%$) of at least 3 months, measured with two or more consecutive HbA1c values; (2) no prescription of glucose-lowering medications during that interval, ± 15 days around measurements; and (3) evidence of clinical monitoring between both measurements (at least one clinical registry during that interval, either a medical or nursing consultation or a clinical measurement record). HbA1c values were analyzed sequentially, from the start date in ECE, until identifying a period of normoglycemia. Then, a multistep algorithm was performed to assess the existence of glucose-lowering medication. First, we classified whether prescriptions in that period contained glucose-lowering medications. If no prescription was found in that period, we sought evidence of continuity in use of medical services, i.e., medical consultations recorded in that period. If there was no evidence of such use, then we considered the pharmacological status as unconfirmed and the case was not recorded as RT2D.

2.3. Independent Variables

Clinical and sociodemographic variables measured at admission and at the end of follow-up (12 months) were considered: (1) Sociodemographic: age, sex assigned at birth,

educational level (no school, basic, middle, high school, university or higher), and monthly income. (2) Clinical: baseline HbA1c levels, systolic/diastolic blood pressure, total cholesterol, HDL, LDL, and triglycerides. (3) Baseline drug therapy: classified as only lifestyle changes, with one, two or more drugs, or with insulin (alone or in combination). (4) Change in body weight: defined as weight at the end of follow-up minus baseline weight.

2.4. Statistical Analysis

Continuous variables were described with means and standard deviations. Categorical variables were presented as frequencies and percentages. Medical records missing baseline or follow-up data were excluded from the analysis. Logistic regression models were defined a priori based on theory and previous evidence [9,13,15,17]. The models included sociodemographic variables (age, sex, income, and educational level) and baseline continuous clinical variables (HbA1c, BMI, blood pressure, triglycerides, HDL, and total cholesterol) that were transformed into tertile binary indicators to minimize assumptions regarding the functional form of the relationship between outcome and independent variables. Weight change was continuous and categorically modeled (weight gain, 0% to less than 5% loss, 5% to less than 10%, and more than 10% weight loss) using weight gain as reference. Baseline pharmacological therapy was modeled according to the categories described above.

Unadjusted (bivariate) models were run for all variables. Results are expressed as odds ratios (ORs) with 95% confidence intervals. In adjusted Model 1, weight change was modeled continuously; in Model 2, categorically. In Model 3, a two-way interaction between weight change categories and BMI tertiles was added to estimate potential interaction effects between baseline BMI on weight loss and RT2D. Due to the low prevalence of RT2D (<1%), models were run with the Firth logistic method; results were very similar and no indication of positivity violation issues was found. The Akaike criterion was used to assess model fit [21].

To facilitate interpretation of interaction terms, marginal probabilities—the predicted probability of achieving RT2D—were estimated for combinations of the interaction terms, keeping independent variables constant. The statistical significance of interaction terms was assessed using Wald's chunk test.

A sensitivity analysis was performed in a subgroup of patients with BMI > 20 kg/m² and age less than 70 years, with the aim of exploring the association between RT2D and weight loss in a population with a lower risk of frailty and/or sarcopenia. This subpopulation was chosen due to operational interests in how to potentially implement a RT2D protocol in the future.

All analyses were performed using StataCorp version 17 software (College Station, TX, USA). A *p*-value < 0.05 was considered statistically significant for all estimates, except for evaluating interaction terms (*p*-value < 0.20).

2.5. Patient and Public Involvement

Except for the fact that an expert patient was involved as an investigator in this study (VV), there was no involvement on the part of people diagnosed with type 2 diabetes or the general public. However, the decision to develop the manuscript from quality control analyses stemmed in part from the fact that research on RT2D has been reported to be a priority for people diagnosed with type 2 diabetes [22].

3. Results

3.1. Population Characteristics

Of the 12,493 patients who fulfilled inclusion criteria at baseline, 8463 (73.1%) had complete clinical information for analysis. Figure 1 presents the flow chart for the selection of records and Table 1 shows the sociodemographic and clinical characteristics. The median follow-up was 393 days. The sample was predominantly female (74.1%), with a mean age of 57.4 ± 11.1 years. The average educational level was 6.7 ± 3.6 years and the reported monthly income was 3993 Mexican pesos, equivalent to 408 international dollars (PPP) at the exchange rate of June 2019. From a clinical perspective, at the beginning of the documented period, 37.6% of patients were overweight and 43.0% obese, with an average BMI of 29.6 ± 5.3 kg/m². Likewise, 78.3% had poor glycemic control (HbA1c > 7%), with an average baseline HbA1c value of $9.2\% \pm 2.4$. Regarding pharmacological treatment, 95.05% of patients received at least one hypoglycemic agent; of these, 47.8% used insulin (alone or in combination).

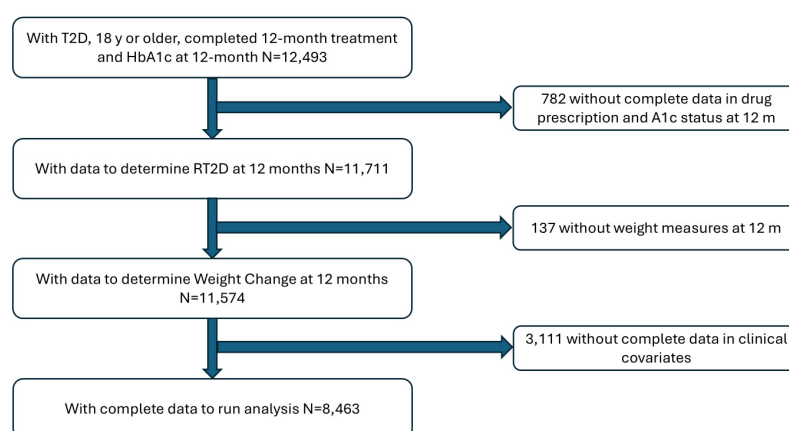


Figure 1. Flow diagram of patient selection from UNEMES-EC electronic medical records (2015–2019).

Table 1. Baseline sociodemographic characteristics of the study population with diabetes in remission and non-remission.

Characteristic	Analytical Sample N = 8463	Not in Remission N = 8390	In Remission N = 73
Sociodemographic variables			
Female sex, <i>n</i> (%)	6270 (74.1)	6215 (74.1)	55 (75.3)
Age, mean (SD), years	57.4 (11.1)	57.4 (11.1)	60.0 (12.3)
18–53 years, <i>n</i> (%)	3002 (35.5)	2979 (35.5)	23 (31.5)
54–62 years, <i>n</i> (%)	2794 (33.0)	2775 (33.1)	19 (26.0)
63–95 years, <i>n</i> (%)	2667 (31.5)	2636 (31.4)	31 (42.5)
Height, mean (SD), cm	155.2 (8.8)	155.2 (8.8)	155.0 (8.7)
Weight, mean (SD), kg	71.5 (14.8)	71.5 (14.8)	73.8 (15.6)
Education, mean (SD), years	6.7 (3.6)	6.7 (3.6)	6.7 (3.5)
Below basic school, <i>n</i> (%)	1783 (21.1)	1766 (21.0)	17 (23.3)
Basic school, <i>n</i> (%)	3556 (42.0)	3524 (42.0)	32 (43.8)
Middle school or above, <i>n</i> (%)	3124 (36.9)	3100 (36.9)	24 (32.9)
Income, mean (SD), Int\$ *	3993 (3955)	3993 (3957)	3970 (3757)
\$0–\$218, <i>n</i> (%)	2821 (33.3)	2800 (33.4)	21 (28.8)
\$219–\$490, <i>n</i> (%)	2918 (34.5)	2885 (34.4)	33 (45.2)
\$491–\$5100, <i>n</i> (%)	2724 (32.2)	2705 (32.2)	19 (26.0)
Clinical parameters			
BMI, mean (SD), kg/m ²	29.6 (5.3)	29.6 (5.3)	30.7 (6.0)
18.5–26.9, <i>n</i> (%)	2831 (33.5)	2812 (33.5)	19 (26.0)
27.0–31.3, <i>n</i> (%)	2830 (33.4)	2810 (33.5)	20 (27.4)
31.4–47.0, <i>n</i> (%)	2802 (33.1)	2768 (33.0)	34 (46.6)

Table 1. Cont.

Characteristic	Analytical Sample N = 8463	Not in Remission N = 8390	In Remission N = 73
Systolic BP, mean (SD), mmHg	124.0 (19.2)	124.0 (19.2)	132.0 (18.5)
78–116, n (%)	2861 (33.8)	2845 (33.9)	16 (21.9)
117–130, n (%)	3320 (39.2)	3298 (39.3)	22 (30.1)
131–240, n (%)	2282 (27.0)	2247 (26.8)	35 (47.9)
Diastolic BP, mean (SD), mmHg	76.7 (10.2)	76.7 (10.2)	77.9 (9.8)
51–70, n (%)	3328 (39.3)	3304 (39.4)	24 (32.9)
71–80, n (%)	3508 (41.5)	3476 (41.4)	32 (43.8)
81–140, n (%)	1627 (19.2)	1610 (19.2)	17 (23.3)
HbA1c, mean (SD), %	9.2 (2.4)	9.2 (2.4)	7.0 (1.6)
3.46–7.9%, n (%)	2915 (34.4)	2859 (34.1)	56 (76.7)
7.91–10.2%, n (%)	2822 (33.3)	2807 (33.5)	15 (20.5)
10.21–18.3%, n (%)	2726 (32.2)	2724 (32.5)	2 (2.7)
Triglycerides, mean (SD), mg/dL	198.4 (119.0)	198.7 (119.2)	160.7 (90.9)
22–136, n (%)	2849 (33.7)	2814 (33.5)	35 (47.9)
136–208, n (%)	2808 (33.2)	2783 (33.2)	25 (34.2)
208–888, n (%)	2806 (33.2)	2793 (33.3)	13 (17.8)
Total cholesterol, mean (SD), mg/dL	186.2 (43.7)	186.2 (43.6)	180.8 (50.6)
40–166, n (%)	2874 (34.0)	2843 (33.9)	31 (42.5)
166–200, n (%)	2780 (32.8)	2759 (32.9)	21 (28.8)
200–397, n (%)	2809 (33.2)	2788 (33.2)	21 (28.8)
HDL-cholesterol, mean (SD), mg/dL	44.4 (13.8)	44.4 (13.8)	45.5 (13.5)
11–38, n (%)	2985 (35.3)	2965 (35.3)	20 (27.4)
38–48, n (%)	2797 (33.0)	2766 (33.0)	31 (42.5)
48–199, n (%)	2681 (31.7)	2659 (31.7)	22 (30.1)
Weight change			
12-month weight change, mean (SD), %	−0.2 (7.1)	−0.2 (5.0)	−3.2 (7.2)
Weight gain, n (%)	4037 (47.7)	4022 (48.0)	15 (20.6)
0 to −4.99%, n (%)	2668 (31.7)	2660 (31.7)	24 (32.9)
−5 to −9.99%, n (%)	1280 (15.1)	1257 (15.0)	23 (31.5)
−10% or more, n (%)	462 (5.5)	451 (5.4)	11 (15.1)
Baseline T2D medical prescription			
Only lifestyle changes, n (%)	418 (4.9)	394 (4.7)	24 (32.9)
One oral medicine, n (%)	1899 (22.4)	1871 (22.3)	28 (38.4)
Two or more oral medications, n (%)	2100 (24.8)	2096 (25.0)	4 (5.5)
Insulin alone or in any combination, n (%)	4046 (47.8)	4029 (48.0)	17 (23.3)

* Income values expressed in 2015. Geary-Khamis international dollars (Int\$). BP = blood pressure; BMI = body mass index; HbA1c = glycated hemoglobin; HDL = high-density lipoprotein.

3.2. Prevalence

The prevalence of type 2 diabetes remission (RT2D) was 0.87% ($N = 73$). By weight change categories, the percentages of patients who achieved RT2D were: 0.37% among those who gained weight, 0.89% among those who lost between 0 and −4.99%, 1.8% among those who lost between −5% and −9.99%, and 2.38% among those who achieved a weight loss of −10% or more. By treatment categories at baseline, the prevalences of RT2D were: 5.74% in those treated only with lifestyle changes, 1.47% in those receiving a single oral drug, 0.19% in those using two or more oral medications, and 0.42% in those using insulin alone or in combination. When the analysis is restricted to the subgroup treated only with lifestyle changes who also achieved weight loss of $\geq 5\%$, the prevalence of RT2D was 11.3% (Figure 2).

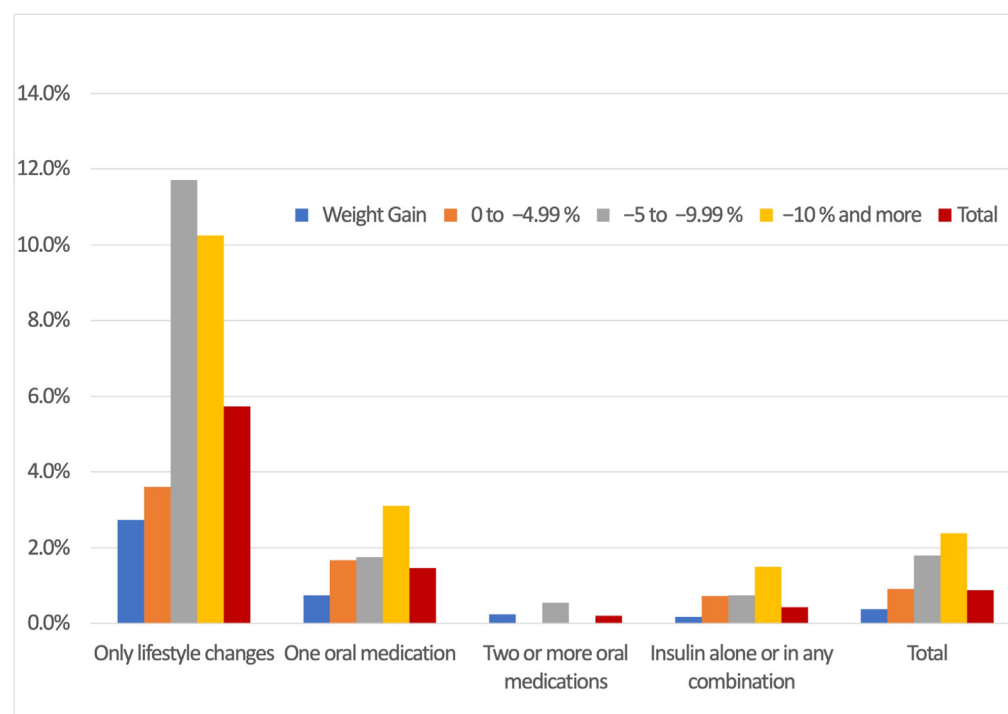


Figure 2. Prevalence of RT2D by baseline medical prescription and 12-month weight loss.

3.3. Predictors of RT2D

In the unadjusted estimations, significant predictors of RT2D were a higher BMI, lower HbA1c, higher systolic blood pressure, lower triglycerides, one or fewer baseline medical prescriptions, and having lost any amount of weight. Model 1 confirmed a statistically significant correlation with continuous weight change. In Model 2, baseline HbA1c was the strongest negative clinical predictor: compared to the lowest tertile, tertile 2 patients had half the odds of achieving remission (OR = 0.47; 95% CI: 0.25–0.85), and those in tertile 3 had a reduction of over 90% (OR = 0.09; 95% CI: 0.02–0.33). The highest tertile of basal triglycerides was also associated with lower odds of remission (OR = 0.49; 95% CI: 0.24–0.98). Conversely, those with higher systolic blood pressure (tertile 3) had higher odds of remission (OR = 2.49; 95% CI: 1.17–5.26). The use of hypoglycemic drugs showed a strong inverse association: compared to patients without hypoglycemic drug therapy, those who used insulin at baseline had much lower odds of achieving remission (OR = 0.16; 95% CI: 0.08–0.31), while those treated with two or more oral medications had the lowest odds observed (OR = 0.04; 95% CI: 0.02–0.13). None of the sociodemographic variables (sex, age, income, education) or BMI showed a significant association with RT2D after adjusting for other covariates. Results are presented in Table 2.

Table 2. Associations between type 2 diabetes remission (RT2D) and sociodemographic and clinical variables: unadjusted and adjusted logistic regression models.

Variable	Unadjusted		Model 1 ^a			Model 2 ^b			Model 3 ^c		
	OR	95% CI	OR	95% CI	<i>p</i>	OR	95% CI	<i>p</i>	OR	95% CI	<i>p</i>
Sociodemographic variables											
Female sex	1.05	0.62–1.78	0.94	0.53–1.64	0.816	0.94	0.53–1.65	0.842	0.96	0.55–1.69	0.888
Age categories											
18–53 years	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
54–62 years	0.89	0.49–1.63	0.63	0.33–1.20	0.159	0.63	0.33–1.20	0.161	0.64	0.34–1.21	0.167
63–95 years	1.51	0.89–2.60	0.73	0.39–1.39	0.339	0.73	0.38–1.38	0.338	0.72	0.38–1.37	0.319
Education level											
Below basic school	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
Basic school	0.93	0.52–1.67	0.94	0.51–1.72	0.831	0.93	0.51–1.71	0.815	0.91	0.49–1.67	0.759
Middle school or above	0.80	0.43–1.48	0.82	0.41–1.61	0.562	0.81	0.41–1.60	0.548	0.77	0.39–1.53	0.462

Table 2. Cont.

Variable	Unadjusted		Model 1 ^a			Model 2 ^b			Model 3 ^c		
	OR	95% CI	OR	95% CI	<i>p</i>	OR	95% CI	<i>p</i>	OR	95% CI	<i>p</i>
Income level											
\$0–\$218	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
\$219–\$490	1.51	0.88–2.61	1.59	0.91–2.79	0.101	1.59	0.91–2.79	0.104	1.62	0.92–2.83	0.092
\$491–\$5100	0.94	0.51–1.74	0.99	0.53–1.85	0.963	0.98	0.52–1.85	0.957	0.98	0.52–1.84	0.952
Clinical and metabolic variables ^d											
BMI, kg/m²											
18.5–26.9	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
27.0–31.3	1.05	0.56–1.96	0.78	0.41–1.48	0.440	0.77	0.41–1.47	0.443	0.68	0.18–2.54	0.572
31.4–47.0	1.80 **	1.03–3.14	1.15	0.63–2.11	0.656	1.13	0.62–2.07	0.689	1.46	0.48–4.46	0.504
Baseline HbA1c, %											
3.46–7.9%	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
7.91–10.2%	0.28 ***	0.16–0.49	0.46	0.25–0.84	0.012	0.47	0.25–0.85	0.013	0.48	0.26–0.87	0.016
10.21–18.3%	0.05 ***	0.01–0.16	0.09	0.02–0.33	<0.001	0.09	0.02–0.33	<0.001	0.09	0.02–0.33	<0.001
Systolic BP, mmHg											
78–116	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
117–130	1.18	0.62–2.22	1.17	0.58–2.35	0.656	1.19	0.59–2.39	0.623	1.19	0.59–2.38	0.630
131–240	2.72 ***	1.52–4.90	2.50	1.18–5.29	0.016	2.49	1.17–5.26	0.017	2.53	1.19–5.35	0.015
Diastolic BP, mmHg											
51–70	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
71–80	1.26	0.74–2.13	0.96	0.54–1.72	0.892	0.94	0.53–1.69	0.842	0.92	0.52–1.65	0.786
81–140	1.47	0.79–2.71	0.73	0.34–1.54	0.407	0.74	0.35–1.57	0.442	0.73	0.34–1.54	0.403
Total cholesterol, mg/dL											
40–166	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
166–200	0.70	0.41–1.22	0.70	0.39–1.25	0.230	0.71	0.40–1.28	0.257	0.70	0.39–1.26	0.234
200–397	0.70	0.40–1.21	0.87	0.46–1.64	0.662	0.88	0.46–1.68	0.705	0.87	0.46–1.67	0.683
HDL-cholesterol, mg/dL											
11–38	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
38–48	1.64 *	0.94–2.88	1.77	0.98–3.19	0.058	1.74	0.97–3.15	0.067	1.77	0.98–3.21	0.058
48–199	1.22	0.67–2.23	1.15	0.59–2.24	0.683	1.13	0.58–2.21	0.729	1.12	0.57–2.19	0.742
Triglycerides, mg/dL											
22–136	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
136–208	0.73	0.43–1.21	0.71	0.41–1.23	0.220	0.70	0.41–1.20	0.195	0.69	0.40–1.19	0.179
208–888	0.38 ***	0.20–0.72	0.49	0.25–0.99	0.046	0.49	0.24–0.98	0.043	0.49	0.25–0.99	0.047
Medical prescription											
Only lifestyle changes	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
One oral medicine	0.25 ***	0.14–0.43	0.25	0.14–0.44	<0.001	0.25	0.14–0.45	<0.001	0.26	0.15–0.45	<0.001
Two or more oral medications	0.03 ***	0.01–0.09	0.04	0.02–0.12	<0.001	0.04	0.02–0.13	<0.001	0.05	0.02–0.13	<0.001
Insulin in any combination	0.07 ***	0.04–0.13	0.15	0.08–0.30	<0.001	0.16	0.08–0.31	<0.001	0.16	0.08–0.31	<0.001
Weight change											
Weight gain	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
0 to –4.99%	2.39 ***	1.27–4.52	—	—	—	1.60	0.83–3.09	0.161	1.21	0.38–3.86	0.745
–5 to –9.99%	4.85 ***	2.54–9.24	—	—	—	2.39	1.21–4.75	0.012	4.25	1.42–12.72	0.010
–10% or more	6.61 ***	3.06–14.26	—	—	—	2.75	1.21–6.27	0.016	2.62	0.41–16.91	0.311
Continuous weight change ^e	0.00 ***	0.00–0.01	0.01	0.00–0.40	0.015	—	—	—	—	—	—
Interaction terms: Weight change × BMI tertiles (Model 3 only)											
Weight gain (reference)	1 (ref)	—	1 (ref)	—	—	1 (ref)	—	—	1 (ref)	—	—
0–4.99% × BMI tertile 1 (ref)	—	—	—	—	—	—	—	—	1 (ref)	—	—
0–4.99% × BMI tertile 2	—	—	—	—	—	—	—	—	1.67	0.30–9.34	0.560
0–4.99% × BMI tertile 3	—	—	—	—	—	—	—	—	1.22	0.27–5.47	0.796
–5 to –9.99% × BMI tertile 1 (ref)	—	—	—	—	—	—	—	—	1 (ref)	—	—
–5 to –9.99% × BMI tertile 2	—	—	—	—	—	—	—	—	0.82	0.15–4.34	0.814
–5 to –9.99% × BMI tertile 3	—	—	—	—	—	—	—	—	0.29	0.07–1.32	0.109
–10% or more × BMI tertile 1 (ref)	—	—	—	—	—	—	—	—	1 (ref)	—	—
–10% or more × BMI tertile 2	—	—	—	—	—	—	—	—	0.89	0.07–10.68	0.925
–10% or more × BMI tertile 3	—	—	—	—	—	—	—	—	1.06	0.12–8.95	0.959
Wald test for interaction (<i>p</i> -value)	—	—	—	—	—	—	—	—	—	—	0.60

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$. ^a Model 1: all covariates adjusted simultaneously; weight change modeled as continuous (kg). ^b Model 2: all covariates adjusted simultaneously; weight change modeled as categorical. ^c Model 3: Model 2 plus two-way interaction between weight change categories and BMI tertiles. ^d Tertiles built based on baseline sample distribution. ^e Weight change analyzed as continuous and categorical in separate models. OR = odds ratio; CI = confidence interval; BP = blood pressure; HbA1c = glycated hemoglobin; HDL = high-density lipoprotein; BMI = body mass index.

3.4. Weight Change and RT2D

In our dataset, the only known causal factor to promote RT2D is weight loss. Taking as reference those who did not lose weight, the point estimates for weight loss categories of 0–4.99%, 5–9.99%, and 10% or more suggested a nonlinear trend in both bivariate (ORs

of 2.42, 4.91, and 6.54) and adjusted Model 2 (ORs of 1.6, 2.39, and 2.75, respectively), but without reaching statistical significance for the first point estimate. In the sensitivity analysis in the population with BMI > 20 kg/m² and age less than 70 years, the results were very similar to those described in Model 2; point estimates and statistical significance did not change.

In Model 3, Wald's test showed that the interaction terms between weight change and BMI tertiles were not statistically significant ($p = 0.60$). Using this model's output, Figure 3 shows the marginal probabilities for the effect of weight loss in RT2D, by baseline tertiles of BMI. The graph shows a crossover in the point estimates, i.e., 10% or more of weight loss is necessary to achieve the maximum probabilities of RT2D in the highest BMI tertile, but not in the lowest tertile. These point estimates suggest an interaction, but 95% confidence intervals are too wide to draw conclusions.

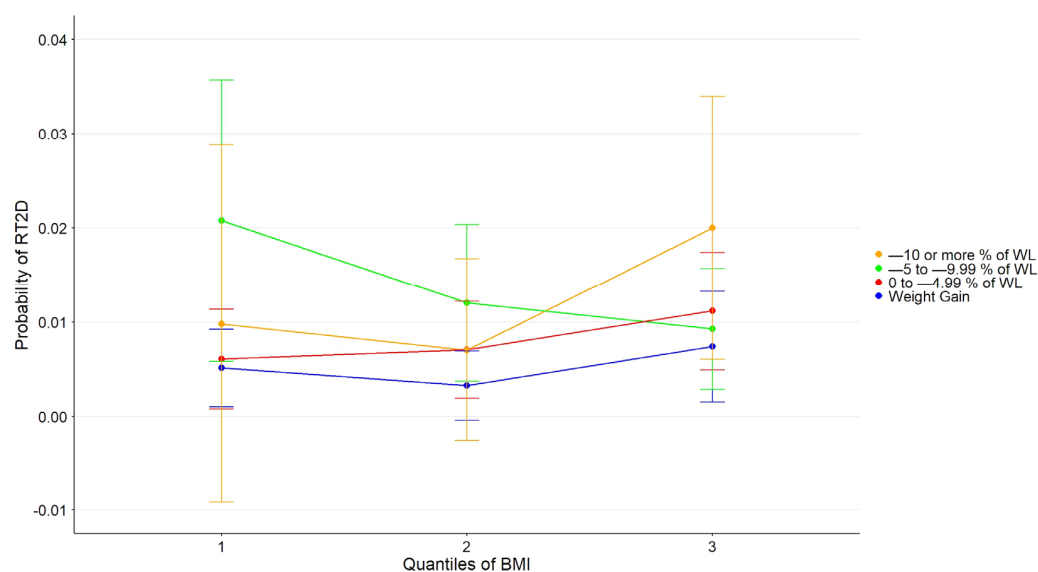


Figure 3. Marginal probabilities of RT2D by interaction categories of BMI and weight change.

4. Discussion

The prevalence of RT2D in regular users of a multidisciplinary diabetes care model, who were initially unable to achieve glycemic control in their primary care clinics, was 0.87%. Negative predictors of RT2D at 12 months were baseline HbA1c, number of pharmacological agents, and triglyceride levels; no epidemiological factors such as age, income, or education level were statistically associated with RT2D. Compared with those who gained weight, losing at least 5% or 10% of body weight was statistically associated with higher odds of remission.

This prevalence was substantially lower than estimates from primary care settings in Scotland (4.8%) [11], Italy (7.8%) [16], Hong Kong (6.1%) [10], and the United States (1% to 3%) [9,23]. Three contextual factors merit consideration when interpreting these findings. First, the population analyzed here comprised patients who had previously failed to achieve metabolic control at their primary care unit and were overall less likely to improve their glucose control and less likely to have maintained pancreatic beta-cell function than the population in most of these previous studies. Second, this population has specific demographics that render it marginalized: low socioeconomic status, with limited formal employment, lower income and educational attainment levels and no access to contributory health insurance, being overall less likely to have the capabilities and resources to comply with diabetes care recommendations. Third, as with many other real-world data analyses, our estimations are an order of magnitude inferior to those of RCT. Despite these physiological and structural disadvantages, the observation of remission

cases demonstrates that RT2D remains clinically attainable for both patients and health systems, even in resource-constrained settings.

The strongest modifiable predictor of RT2D in our analysis was a weight loss of 10% or greater. Point estimates suggest a non-linear dose–response relationship between weight change and remission, concordant with observations across heterogeneous populations [6,15,16]. From a mechanistic perspective, remission is hypothesized to depend upon substantial reduction of ectopic fat deposits in the pancreas and the liver, reaching a critical threshold that permits functional recovery [17]. According to this framework, lipid depletion would restore both hepatic sensitivity to insulin and beta-cell insulin secretory function. Notably, the lack of statistically significant interaction between baseline BMI and weight change in our sample could be attributed to limited statistical power, given the number of events ($n = 73$). However, this finding also underscores the clinical recommendation of promoting substantial weight loss without regard to baseline adiposity.

We confirmed that lower HbA1c, fewer pharmacological agents, and lower triglyceride levels can be considered baseline clinical predictors of RT2D, consistent with previous research [13,24]. A high HbA1c reflects greater glucotoxicity and likely greater deterioration of beta-cell function, which hinders functional recovery. The negative association with intensive basal therapy likely reflects that these patients were clinically assessed as having lower metabolic capacity to manage their diabetes at baseline, rather than the drugs themselves reducing the likelihood of RT2D.

Elevated triglyceride levels were inversely associated with remission and may also be considered a modifiable predictor of RT2D in the Mexican context. For a patient to have high triglycerides, three conditions must be present: failure in physiological homeostasis, a diet that promotes high levels, and lack of pharmacological treatment to lower them. The type of diet followed is modifiable. The dietary recommendations at the time of this study promoted a high-carbohydrate diet for people with T2D—a health system-modifiable factor.

Sociodemographic factors such as age, sex, educational level, and income were not statistically significant predictors of RT2D. This finding contrasts with what has been reported in populations in high-income countries [11], where social disparities often mark the prognosis of patients. This could be due to the demographic characteristics of the user population of UNEMES-EC described above. It can also be due to the selective inclusion of consistent service users, which may have homogenized healthcare access and self-management capacity across socioeconomic strata. Lastly, it could also reflect the potential effect of the multidisciplinary model of UNEMES-EC in mitigating structural barriers to diabetes control and remission, reducing the effect of sociodemographic inequities.

In order to inform a future implementation of a RT2D program, we found meaningful baseline predictors. The odds of remission were far lower among people in the highest tertile of HbA1c, using insulin in any combination, and using two or more oral hypoglycemic drugs. In addition, we found a positive association between high systolic blood pressure at baseline and the likelihood of remission. While selection bias cannot be ruled out (our sample is likely to include individuals with uncontrolled hypertension but mild T2D), this association has been previously reported in randomized trials [14]. Replication of these findings warrants further exploration of potential mechanistic effects of antihypertensive drugs.

A critical finding of this study is the potentially substantial underestimation of RT2D prevalence arising from clinical protocols that do not consider RT2D as a goal or achievable clinical state. In routine practice, physicians typically maintain treatment with hypoglycemic agents despite patients achieving normoglycemic levels, as current guidelines lack explicit frameworks for therapeutic de-escalation when remission is suspected. We identi-

fied that approximately 18% of our sample exhibited this pattern: patients with near-normal glucose levels after substantial weight loss, who were still on one oral medication—mostly metformin. These cases might represent an “occult remission” not captured by conventional surveillance systems. Given the profound implications for clinical practice and health policy, this subgroup will be the subject of an in-depth analysis in an independent publication.

To our knowledge, this is the first study to document the prevalence of RT2D and its strong link to weight loss in a large sample of the Mexican population receiving exclusively primary care services without bariatric surgery. Our findings challenge the prevailing notion that remission is confined to high-income health systems or patients with controlled diabetes, demonstrating instead that RT2D constitutes a realistic therapeutic target for patients in Mexico and comparable resource-limited contexts.

Among the strengths of this work are the substantial sample size ($N = 8463$) and the analysis of real public healthcare services rather than a controlled clinical trial.

However, we recognize important limitations. There is selection bias in this analysis—as it includes only consistent users of UNEMES-EC—which impedes generalizing these results to the entire user group of UNEMES-EC. These results cannot be extrapolated to the general Mexican population with T2D, because UNEMES-EC users are skewed towards those who failed to achieve metabolic control in their primary care units, of lower income strata, without formal jobs, and without social security. This results in a different distribution across socioeconomic and clinical variables, such as the high preponderance of women (74.1%) in UNEMES-EC and in our analytical sample.

Our prevalence estimations are most likely affected by the fact that those patients with regular data, i.e., A1c records, should also be more willing and able to comply with treatment. While losing external representativity, we gained more internal validity by not resorting to imputation methods under a non-missing at random assumption. In sum, our prevalence estimations reflect the scenario where UNEMES-EC users regularly attend the multidisciplinary services. This estimation should be higher than the overall RT2D prevalence in UNEMES-EC, but lower than in overall Mexicans with a diagnosis of T2D (due to the marginalized and uncontrolled status of UNEMES-EC target population).

A major limitation is the absence of data on disease duration since RT2D occurs more often in the early years of the disease. The lack of detailed dietary information limits our ability to explore deep causal mechanisms. Finally, the lack of extended follow-up precludes assessment of remission durability. These limitations, instead of invalidating the results, define a critical path for clinical and epidemiological research on diabetes remission in the region.

This study establishes the clinical feasibility of achieving RT2D in clinically uncontrolled patients in primary care settings using weight loss-focused strategies. Our sensitivity analysis suggests this approach may be optimally targeted toward patients with low frailty risk (i.e., younger than 70 years and with BMI > 20) during early stages of the natural course of the disease, where diabetes management can be achieved through lifestyle changes. Notably, when analyzing those who lost at least 5% of their weight based on lifestyle changes alone, the prevalence of remission reached 11.25%, a figure very close to the 11.5% reported by the Look AHEAD study [13].

These results suggest that implementation of a more intensive and accelerated weight loss protocol in the Mexican public health system could yield a positive effect in RT2D rates. Since it has been documented that achieving RT2D, even transiently, reduces the risk of secondary complications such as cardiovascular events, chronic kidney disease and angiopathies [16,25], the benefits of such implementation could be substantial, both for society and for the patients themselves.

Author Contributions: Conceptualization, V.E.V.-D.; methodology, V.E.V.-D., J.E.-M., R.M.-M. and E.M.-F.; formal analysis, V.E.V.-D. and R.M.-M.; investigation, V.E.V.-D., J.E.-M. and E.M.-F.; data curation, V.E.V.-D. and N.A.-P.; writing—original draft preparation, V.E.V.-D.; writing—review and editing, J.E.-M., R.M.-M., R.L.-R., E.M.-F., N.A.-P., D.R.-V. and I.C.-N.; supervision, I.C.-N. All authors have read and agreed to the published version of the manuscript.

Funding: V.E.V.D. and N.A.P. received a scholarship from the Secretariat of Science, Humanities, Technology and Innovation (SECIHTI), Mexico (formerly CONAHCYT). This research received no additional external funding.

Institutional Review Board Statement: This manuscript derives from quality assessment and service monitoring activities conducted under CENAPRECE governance (2019–2023). Consistent with national regulations, epidemiological surveillance and institutionalized public health program evaluation constitute public health practice rather than human subjects research, thereby exempting this work from prospective research ethics committee review. All analyses employed rigorously de-identified secondary databases, ensuring participant anonymity. Electronic health record handling and data processing adhered strictly to Mexican data protection statutes and Ministry of Health regulatory frameworks.

Informed Consent Statement: Not applicable. All analyses employed rigorously de-identified secondary databases, ensuring participant anonymity.

Data Availability Statement: The datasets analyzed during the current study are not publicly available due to institutional regulations and legal restrictions related to the protection of personal health information under Mexican law. However, the data may be requested for academic or public health research purposes through a formal application to the National Center for Disease Prevention and Control (CENAPRECE) of the Mexican Ministry of Health.

Acknowledgments: The authors wish to thank the clinical teams at the UNEMES-EC units for their dedication to patient care and data collection, and to the CENAPRECE team for institutional support.

Conflicts of Interest: Ruy López-Ridaura was employed by PEMEX. The other authors declare no conflicts of interest.

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