


BMJ Open Integrated Measurement for Early Detection (MIDO) as a digital strategy for timely assessment of non-communicable disease profiles and factors associated with unawareness and control: a retrospective observational study in primary healthcare facilities in Mexico

Héctor Gallardo-Rincón,¹ Alejandra Montoya ², Rodrigo Saucedo-Martínez,² Ricardo Mújica-Rosales,² Lorena Suárez-Idueta,² Luis Alberto Martínez-Juárez,^{2,3} Christian Razo,⁴ Rafael Lozano,⁴ Roberto Tapia-Conyer^{2,5}

To cite: Gallardo-Rincón H, Montoya A, Saucedo-Martínez R, *et al*. Integrated Measurement for Early Detection (MIDO) as a digital strategy for timely assessment of non-communicable disease profiles and factors associated with unawareness and control: a retrospective observational study in primary healthcare facilities in Mexico. *BMJ Open* 2021;**11**:e049836. doi:10.1136/bmjopen-2021-049836

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online. (<http://dx.doi.org/10.1136/bmjopen-2021-049836>).

Received 03 February 2021

Accepted 21 July 2021



© Author(s) (or their employer(s)) 2021. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

Correspondence to

Dr Alejandra Montoya; airainmr@fundacioncarlosslim.org

ABSTRACT

Objectives The Carlos Slim Foundation implemented the Integrated Measurement for Early Detection (MIDO), a screening strategy for non-communicable diseases (NCDs) in Mexico as part of CASALUD, a portfolio of digital health services focusing on healthcare delivery and prevention/management of NCDs. We investigated the disease profile of the screened population and evaluated MIDO's contribution to the continuum of care of the main NCDs.

Design Using data from MIDO and the chronic diseases information system, we quantified the proportion of the population screened and diagnosed with NCDs, and measured care linkage/retention and level of control achieved. We analysed comorbidity patterns and estimated prevalence of predisease stages. Finally, we estimated characteristics associated with unawareness and control of NCDs, and examined efficacy of the CASALUD model in improving NCD control.

Setting Public primary health centres in 27/32 Mexican states.

Participants Individuals aged ≥ 20 years lacking healthcare access.

Results From 2014 to 2018, 743 000 individuals were screened using MIDO. A predisease or disease condition was detected in $\geq 70\%$ of the population who were unaware of their NCD status. The screening identified 38 417 new cases of type 2 diabetes, 53 133 new cases of hypertension and 208 627 individuals with obesity. Dyslipidaemia was found in 77.3% of individuals with available blood samples. Comorbidities were highly prevalent, especially in people with obesity. Only 5.47% (n=17 774) of individuals were linked with their corresponding primary health centre. Factors associated with unawareness of and uncontrolled NCDs were sex, age, and social determinants, for example, rural/urban

Strengths and limitations of this study

- The Measurement for Early Detection (MIDO) screening strategy contributes to betterment of public health by identifying predisease states of the most common non-communicable diseases (NCD) and thereby allowing early intervention, particularly in disadvantaged populations lacking healthcare access.
- Another strength of this study is the very large sample size (743 000 individuals screened over a 4-year period).
- Although MIDO did not use gold-standard tests for diagnosing type 2 diabetes (fasting plasma glucose and oral glucose tolerance tests), the simple and accessible approach we used (fasting capillary glucose and random capillary glucose) is reliable for identifying undiagnosed diabetes as well as predicting individuals at risk.
- Possible limitations include the assumptions that disease distribution and unawareness are the same in the studied population as in the surveys, and that all the individuals screened using MIDO could be followed within the individual administrative public health centre database.
- Because of selection bias, the results of the MIDO screening cannot be used as an estimate of NCD prevalence.

environment, access to healthcare service, and education level. Patients with type 2 diabetes treated at clinics under the CASALUD model were more likely to achieve disease control (OR: 1.32, 95% CI: 1.09 to 1.61).

Conclusion Patient-centred screening strategies such as MIDO are urgently needed to improve screening, access, retention and control for patients with NCDs.

INTRODUCTION

Non-communicable diseases (NCDs), such as ischaemic heart disease, chronic kidney disease and type 2 diabetes mellitus (T2DM), are the three leading causes of death in Mexico.¹ NCDs were responsible for 80% (67 535) of total deaths in the country in 2019. T2DM is the leading cause of years lived with disability.¹ High fasting plasma glucose, high body mass index (BMI), high blood pressure and suboptimal diet have been recognised as the top risk factors associated with NCDs, accounting for more than half of attributable deaths and disability-adjusted life-years.¹

Although T2DM and hypertension are recognised as public health problems, according to the Mexican National Health and Nutrition Survey (2016), 40% of the population with hypertension and 29% of those with T2DM are unaware of their condition.^{2 3} Moreover, it is recognised that only 46% of people with hypertension and 16% of people with T2DM achieve control of their condition.³ Additionally, lipid disorders contribute to the development of NCDs such as cardiovascular disease, which has been the main cause of mortality in Mexico in recent years. The 2012 Ensanut study reported that approximately 31% of Mexican adults had hypercholesterolaemia and 49% had hypertriglyceridaemia.⁴

It is also known that multiple comorbidities are highly common in patients with T2DM, especially with increasing age.⁵ Comorbidities, including cardiovascular and neurological complications, diabetic retinopathy and diabetic nephropathy, have been associated with poor health outcomes. In the case of patients with cardiovascular diseases, disorders of carbohydrate metabolism, thyroid disease, bronchial asthma, varicose disease, chronic hepatitis and urolithiasis are common in patients with ischaemic heart disease or chronic heart failure.^{6 7} Moreover, evidence from other countries suggests that the cost of illness is substantially higher for individuals with comorbidities and represents a major challenge for healthcare systems.⁸

During the past decade, the Mexican government has implemented plans, regulations, policies and programmes to tackle NCDs, mainly focusing on nutrition; however, few population-based screening programmes have been implemented.⁹ Only two studies have been published investigating screening and prevention in primary healthcare at the national level, and these reported little, if any, benefit.^{10 11} Moreover, the traditional screening approach only reaches the population already seeking healthcare services at health facilities. As a result, nearly half of patients with T2DM present tissue damage by the time they are diagnosed,¹² and a large number of people with NCDs remain undiagnosed. In traditional curative health systems, the lack of early strategies for NCD detection and

effective treatments to achieve control and prevent long-term complications have been recognised as important limitations to prevent microvascular and macrovascular complications during the latent period of disease.^{13 14}

To address the aforementioned limitations, in 2008 the Carlos Slim Foundation ('Fundación Carlos Slim') in Mexico created an innovative model entitled CASALUD (from the Spanish words for 'CASA' 'home' and SALUD 'health'),¹⁵ which is an innovative healthcare system leveraging digital health resources that includes strategies for prevention, early detection and control of the principal NCDs based on international best practices. Within CASALUD, the Chronic Diseases Information System (SIC) and the Integrated Measurement for Early Detection (MIDO)¹⁶ were developed and implemented as digital, interconnected platforms enabling health professionals to perform proactive community-level prevention of obesity, T2DM, hypertension and dyslipidaemia (when laboratory tests were available).

In this paper, we aim to describe the complete disease profile (risk, predisease, disease and comorbidities) of the screened Mexican population, and evaluate MIDO's contribution to the continuum of care from screening to control of the main NCDs.

METHODS

This analysis included a total of 743 000 people aged ≥ 20 years, who were screened by MIDO from 2014 to 2018 in 137 public primary health centres (PHCs) among 27 of the 32 states in Mexico.¹⁷ We used data from the MIDO and SIC digital platforms, both of which are blinded databases of administrative records. As all data were anonymised prior to access, informed consent was not required. Permission to use the data was granted by the Mexican Ministry of Health, according to a signed agreement between the Ministry and the Carlos Slim Foundation, which stipulates that the Foundation may perform technical analyses to inform about the progress of the NCD programmes in order to provide guidance that may contribute to improvements in current policy. Furthermore, this study was conducted in accordance with the principles of the Declaration of Helsinki and local laws and regulations. SIC enables the registry of medical care provided by PHCs to people living with NCDs, including information on patient retention, completeness of diagnosis and treatment protocols, and metabolic control.

MIDO's platform focuses on risk assessment of each individual based on core measurements such as BMI, waist circumference, blood pressure and capillary glucose (CG). Data are also collected regarding smoking and sleeping habits, as well as responses from the Finnish Diabetes Risk Score (FINDRISC) questionnaire.¹⁸ Additionally, in PHCs with laboratory facilities, MIDO assessment also includes a lipid panel. Details on the MIDO assessment strategy are described in online supplemental figure 1.

Individuals are classified as having a disease if they reported a history of prior diagnosis. A previous diagnosis of T2DM or hypertension was identified by self-report if the individual knew about their condition. For T2DM, individuals are classified as having a new diagnosis if their fasting CG was ≥ 126 mg/dL or a random CG value was ≥ 200 mg/dL.¹⁹ For hypertension, the cut-off point is systolic blood pressure (SBP) ≥ 140 mm Hg or diastolic blood pressure (DBP) ≥ 90 mm Hg²⁰; for obesity, the threshold is BMI ≥ 30 kg/m².²¹ Dyslipidaemia is defined as total cholesterol ≥ 200 mg/dL and low-density lipoprotein (LDL) > 70 mg/dL, high-density lipoprotein (HDL) < 40 mg/dL for men (< 50 mg/dL for women) or hypertriglyceridaemia (triglycerides ≥ 150 mg/dL).²² The same thresholds are used for both diagnosis and control of hypertension and dyslipidaemia. T2DM control is defined in screening as having a fasting CG < 130 mg/dL²³ or random CG < 140 mg/dL,²⁴ and glycated haemoglobin (A1c) $< 7\%$ in the PHC medical records.²³

The 'predisease' stage includes individuals identified with pre-T2DM (fasting glucose 100–125 mg/dL),¹⁹ prehypertension (SBP 130–139 mm Hg or DBP 85–89 mm Hg)²⁵ and preobesity (overweight; BMI 25–29.9 kg/m²).²⁶ Comorbidities are defined as the presence of more than one diagnosis or prediagnosis within the same individual. Finally, individuals are classified as 'disease not diagnosed' when all previously mentioned values and measurements fell within normal ranges.

Laboratory tests are only included in PHCs with laboratory facilities and in those individuals who self-reported 12 hours of fasting. Lipid profile is measured using a venous blood sample for at least one parameter: total cholesterol, LDL cholesterol, HDL cholesterol and triglycerides.

MIDO includes an algorithm to profile the risk of each individual, which enables health professionals to provide counselling to patients and prescribe changes in lifestyle. In addition, individuals who are identified as having an NCD but are unaware of their disease before MIDO screening are referred to their corresponding PHC for further confirmation and clinical management. We applied the continuum of care framework to identify and quantify the flow of people, through all stages; namely, detection, treatment and control.

Statistical analysis

First, we conducted a descriptive analysis of the main sociodemographic characteristics and disease profiles of the screened population, using mean \pm SD or frequency and proportion (%), according to the scale of the variable. The distributions of diseases, prediseases and lipid profiles were estimated as proportions, and then stratified according to the three categories of the MIDO integrated risk assessment score: < 10 points, low; > 10 and < 13 , moderate and > 13 , high (based on the FINDRISC scale,¹⁸ to estimate the sensitivity and specificity by category. Missing data were not imputed.

We then described the continuum of care using logistic regression models to evaluate factors associated with a

lack of awareness and control among people with hypertension or diabetes. Finally, we evaluated the contribution of CASALUD in closing the gap with respect to disease control for those who sought medical care at a PHC. To compare PHCs with and without CASALUD, a logistic regression model was fitted, in which the dependent variable was achieving control (glycated haemoglobin (A1c), CG, blood pressure or total cholesterol levels). Models were adjusted according to sex, age, time since diagnosis, number of medical visits, and comorbidities. A $p < 0.05$ was considered statistically significant, and all analyses were performed using Stata V.15 (StataCorp).²⁷

Patient and public involvement

Neither patients nor the public were involved in the design of this research.

RESULTS

Table 1 shows the principal characteristics of the population screened using MIDO (N=743 000; approximately 55% of the total population covered by the 137 PHCs). The average age was 41.5 (SD 14.8) years; nearly half of the population (49.2%) was between 20 and 39 years. Nearly 70% of screened individuals were women, and almost 11% reported being an active smoker. Parental history of T2DM was identified in 22.5% of the population. Based on MIDO's integrated risk assessment, 35.1% of the population was classified as having a high risk of disease, 16.2% was classified as having moderate risk, and 48.5% were identified as having low risk.

The overall disease profile of the population screened using MIDO was as follows: 89.8% of the population had a disease or predisease condition (reported by previous diagnosis or identified during the screening). Less than 5% of screened individuals had a previous diagnosis of T2DM or hypertension, with controlled and uncontrolled values in the same proportion. One-third of those screened had a disease newly diagnosed by MIDO (T2DM, hypertension, obesity or dyslipidaemia), and half of the population had a predisease diagnosis (pre-T2DM, prehypertension or preobesity/overweight) (table 2).

The number of comorbidities was higher with increased age and among women. Among people with obesity (the most common diagnosis at 29.4% of the screened population), the rates of comorbidities were as follows: 21.29%, no comorbidity; 4.13%, comorbid with hypertension; 1.54%, T2DM; 0.36%, dyslipidaemia; 0.65%, T2DM and hypertension; 0.06%, hypertension and dyslipidaemia; 0.04%, T2DM and dyslipidaemia; and 0.01%, T2DM, hypertension and dyslipidaemia.

Nearly 30% of the population had obesity and 37.5% had preobesity (overweight) at the time of screening. In the case of T2DM, 4.1% of cases were previously diagnosed and fewer than 40% were controlled, according to CG results. T2DM was detected in 5.8% (38,417 individuals) of the population screened with MIDO, and pre-T2DM was identified in 13.4%. Regarding hypertension,

Table 1 Main characteristics of participants screened using MIDO's integrated assessment

N=743 000	
Sociodemographic characteristics	
Sex	
Female	516 577 (69.5)
Male	226 423 (30.5)
Age (years)*	
20–39	345 929 (49.2%)
40–59	265 699 (37.8%)
≥60	91 220 (13%)
Lifestyle and risk factors	
Smoking (yes, within past 12 months)†	75 520 (10.7)
Parental history of diabetes‡	141 363 (22.5)
Anthropometrics	
Height (cm)	159.1±16.3
Weight (kg)	70.5±15.3
BMI (kg/m ²)	27.8±5.3
Waist circumference, cm	91.5±13.8
Biomarkers§	
SBP (mm Hg)	116.8±16.8
DBP (mm Hg)	72.2±11.2
Fasting CG (mg/dL)	104.4±41.4
Non fasting CG (mg/dL)	116.4±50.1
Total cholesterol (mg/dL)	171.1±51.9
LDL cholesterol (mg/dL)	90.9±30.8
Triglycerides (mg/dL)	178.3±100.7

Data are shown as n (%) or mean±SD.

*N=702 848

†N=708 823

‡N=628 280

§Lipid profile was measured in only 5% of the sample (n=38 855).

BMI, body mass index; CG, capillary glucose; DBP, diastolic blood pressure; LDL, low-density lipoprotein; MIDO, Integrated Measurement for Early Detection; SBP, systolic blood pressure.

6.1% of individuals had a previous diagnosis, and nearly 60% had blood pressure values considered to be adequately controlled. Hypertension was diagnosed using MIDO in 7.4% (53,133 individuals) of the population and 19.2% were diagnosed with prehypertension (table 2). Regarding individuals' lipid profiles (laboratory tests, n=38 855), 77.3% had at least one type of dyslipidaemia, with low HDL cholesterol being the most common type (67.2%), followed by hypertriglyceridaemia (46.5%) and high total cholesterol (27.6%), as shown in table 2.

Males and people who were younger, non-smokers, overweight or obese, without a parental history of T2DM, lived in urban municipalities, lacked access to health services and with lower education levels were more likely to be unaware that they were living with T2DM (table 3). Similar factors were found for hypertension unawareness,

Table 2 MIDO screening results

Population screened (N=743 000)	n (%)
Previous disease,* controlled	32 234 (4.3)
Previous disease,* uncontrolled	30 912 (4.2)
Disease detected†‡	273 170 (36.8)
Predisease detected†§	393 742 (53.0)
Disease not detected	190 832 (25.7)
Screening of nutritional status according to BMI classification (N=709 635)	
Underweight	8 575 (1.2)
Normal weight	226 575 (31.9)
Overweight (preobesity)	265 858 (37.5)
Obesity	208 627 (29.4)
Screening of hypertension (N=718 003)	
Normal	484 016 (67.4)
Controlled hypertension (previous diagnosis)	25 566 (3.6)
Uncontrolled hypertension (previous diagnosis)	17 652 (2.5)
Hypertension (new diagnosis)	53 133 (7.4)
Prehypertension	137 636 (19.2)
Screening of T2DM (N=660 874)	
Normal	507 087 (76.7)
Controlled T2DM (previous diagnosis)	10 437 (1.6)
Uncontrolled T2DM (previous diagnosis)	16 668 (2.5)
T2DM (new diagnosis)	38 417 (5.8)
Pre-T2DM	88 265 (13.4)
Screening of dyslipidaemia¶	
Any dyslipidaemia (N=39 335)	30 415 (77.3)
High total cholesterol (N=38 855)	10 704 (27.6)
High LDL cholesterol (N=9317)	3 472 (37.3)
Low HDL cholesterol (N=22 861)	15 353 (67.2)
Hypertriglyceridaemia (N=35 394)	16 445 (46.5)

*Includes T2DM or hypertension.

†In total, 74.4% of the screened population first became aware of having a disease or predisease through MIDO screening.

‡Includes T2DM, hypertension, dyslipidaemia and obesity.

§Includes pre-T2DM, prehypertension and overweight.

¶Lipid profile assessment is not part of the core measurements of MIDO. It was measured only in PHCs with laboratory facilities.

BMI, body mass index; HDL, high-density lipoprotein; LDL, low-density lipoprotein; MIDO, Integrated Measurement for Early Detection; SBP, systolic blood pressure; T2DM, type 2 diabetes mellitus.

but older age and rural residence were also commonly observed. In people with a previous diagnosis of T2DM, poor glucose control was more likely in men, older people, nonsmokers, individuals with a parental history of T2DM, those with obesity and residents of rural municipalities (table 3).

Table 3 Factors associated with unawareness of and uncontrolled T2DM and hypertension among the population screened using MIDO

	T2D		Hypertension	
	Unawareness n=48953 OR (95% CI)	Uncontrolled n=19348 OR (95% CI)	Unawareness n=74028 OR (95% CI)	Uncontrolled n=32689 OR (95% CI)
Sociodemographic characteristics				
Sex				
Female (reference)	1.00	1.00	1.00	1.00
Male	1.16 (1.12 to 1.21)	1.13 (1.06 to 1.21)	1.44 (1.39 to 1.49)	1.33 (1.27 to 1.4)
Age (years)				
20–39 (reference)	1.00	1.00	1.00	1.00
40–59	0.88 (0.83 to 0.92)	2.15 (1.99 to 2.34)	0.8 (0.77 to 0.83)	1.84 (1.72 to 1.96)
≥60	0.92 (0.87 to 0.98)	1.76 (1.61 to 1.92)	1.26 (1.20 to 1.33)	2.68 (2.50 to 2.87)
Lifestyle and risk factors				
Current smoker				
No (reference)	1.00	1.00	1.00	1.00
Yes	0.47 (0.44 to 0.50)	0.87 (0.80 to 0.93)	0.88 (0.83 to 0.92)	1.04 (0.99 to 1.09)
Parental history of diabetes				
No (reference)	1.00	1.00	1.00	1.00
Yes	0.38 (0.037 to 0.40)	1.25 (1.18 to 1.35)	0.21 (0.21 to 0.23)	1.04 (0.98 to 1.10)
BMI category				
Normal weight (reference)	1.00	1.00	1.00	1.00
Overweight (preobesity)	1.09 (1.03 to 1.15)	0.98 (0.91 to 1.07)	1.04 (0.99 to 1.09)	1.28 (1.2 to 1.4)
Obesity	1.14 (1.08 to 1.20)	1.05 (0.97 to 1.15)	1.06 (1.02 to 1.11)	1.92 (1.80 to 2.06)
Social determinants				
Rural–urban stratification				
Rural (reference)	1.00	1.00	1.00	1.00
Urban	1.45 (1.38 to 1.52)	0.64 (0.60 to 0.69)	0.92 (0.88 to 0.96)	0.79 (0.74 to 0.83)
Lacking access to health services	1.03 (1.03 to 1.04)	0.99 (0.98 to 0.99)	1.07 (1.06 to 1.08)	0.98 (0.97 to 0.99)
Low education level	1.02 (1.01 to 1.03)	0.98 (0.98 to 0.99)	1.09 (1.09 to 1.10)	1.02 (1.02 to 1.03)

BMI, body mass index; MIDO, Integrated Measurement for Early Detection; T2DM, type 2 diabetes mellitus.

We found that the MIDO integrated risk assessment was a useful way to detect NCDs and prediseases in this population. The disease profile distribution is presented in table 4. People without a disease diagnosis were mostly categorised as having a low risk of disease (90.06%), and only 2.61% were categorised as having high risk. Among those participants with predisease, 43.13% and 48.71% of people with pre-T2DM and prehypertension were categorised as high risk, respectively; for preobesity (overweight), 27.88% had moderate risk and nearly the same proportion (26.65%) were categorised as having high risk. The majority (83.4%) of people with obesity were classified as high risk. More than half of individuals with a new diagnosis of T2DM or hypertension were in the high-risk group (55.78% and 59.14%, respectively). Finally,

approximately half of participants with an altered lipid profile were categorised as high risk.

Continuum of care

Among all individuals screened using MIDO who received a new diagnosis of at least one NCD, only 5.47% (n=17774) sought health services for treatment at a PHC, according to SIC records; this represents a proportion of 94.6% with a treatment gap. Only 23.1% of the population treated for T2DM had achieved acceptable glycaemic control (A1c<7%), 40.1% of patients treated for hypertension achieved a normal blood pressure, fewer than 20% of patients treated for dyslipidaemia had decreased total cholesterol levels, and only 4.6% of patients treated for obesity reduced their weight (online supplemental figure 2). Further, the median number of days until

Table 4 Distribution of detected disease profiles according to risk category, based on the MIDO questionnaire

	Low	Moderate	High	Sensitivity,%	Specificity, %	Area under the ROC curve in high/very high risk coef. (95% CI)
Disease not detected	90.06	7.33	2.61			–
Overweight	45.48	27.88	26.65			–
Pre-diabetes	38.98	17.89	43.13			–
Prehypertension	33.33	17.96	48.71			–
Obesity	6.47	10.14	83.4			–
Type 2 diabetes mellitus	28.21	16	55.78	63.4	66.4	0.65 (0.64 to 0.65)
Hypertension	25.11	15.75	59.14	63.6	68.0	0.55 (0.54 to 0.56)
High total cholesterol	28.8	19.73	51.48	51.5	59.2	0.55 (0.54 to 0.56)
High LDL	35.63	16.94	47.43	46.2	60.8	0.53 (0.52 to 0.54)
Low HDL	30.61	18.08	51.31	47.4	63.9	0.55 (0.54 to 0.56)
High triglycerides	35.68	18.11	46.21	51.3	62.1	0.56 (0.55 to 0.57)
Any dyslipidaemia	34.61	18.63	46.76	46.8	66.7	0.56 (0.55 to 0.57)

HDL, high-density lipoprotein; LDL, low-density lipoprotein; MIDO, Integrated Measurement for Early Detection; ROC, receiver operating characteristic.

starting treatment was 344 (IQR: 124–1708) after having received a diagnosis and the first visit to a PHC, with a significant difference in days according to disease: 260 (IQR: 35–649) for T2DM, 323 (IQR: 82–684) for hypertension, 373 (IQR: 108–732) for obesity and 569 (IQR: 178–903) for dyslipidaemia.

Finally, we found that people who received treatment at a PHC that followed the CASALUD model were 32% (OR: 1.32, 95% CI: 1.09 to 1.61) more likely than those treated at a non-CASALUD PHC to achieve T2DM control, adjusting by sex, age, time since detection, time since diagnosis, number of medical consultations and comorbidities (figure 1). This result was not observed for hypertension or dyslipidaemia.

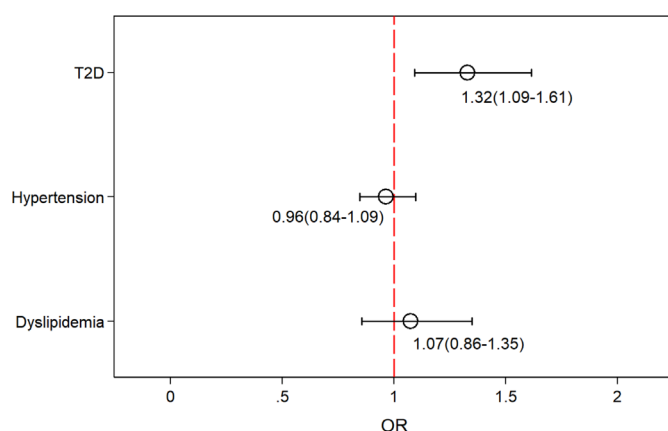


Figure 1 Control of NCDs at PHCs with versus without CASALUD. OR adjusted by sex, age, time from diagnosis, number of medical consultations and comorbidities. NCD, non-communicable disease; PHC, primary health centre; T2DM, type 2 diabetes mellitus.

DISCUSSION

This study presents the first findings about the contribution of the MIDO strategy in screening, detection, treatment and control of NCDs in the adult Mexican population lacking healthcare access. MIDO screening for T2DM, hypertension and obesity was achieved in approximately half of the population (N=743 000) covered by 137 PHCs in 27 states of Mexico. Dyslipidaemia is not included in the core measurements of MIDO's integrated risk assessment, but as some PHCs have a laboratory facility, lipid profile was included in the analysis of the NCD profile, although for only 5.2% of the total screened population. The large difference between the proportion of people screened for T2DM, hypertension and obesity versus those also screened for dyslipidaemia reflects the importance of having tools to identify populations at risk that can be easily applied in almost any setting, as previously recognised (CG, anthropometric measures, blood pressure and validated questionnaires such as the FINDRISC).²⁸ An advantage of applying validated questionnaires is that cut-points can be adapted to the local context, to maximise their predictive capacity and sensitivity.²⁹

A large proportion of undiagnosed NCDs among the screened population were identified using MIDO. Our estimations showed that more than half of people with a T2DM diagnosis were unaware of their condition. These results are aligned with previous estimations; the WHO reported that between 24% and 62% of people with diabetes in a sample of seven countries were undiagnosed and untreated.³⁰ According to the National Health and Nutrition Survey, Mexico has an undiagnosed T2DM prevalence of 30%.³ In the case of hypertension, our

results are also aligned with those previously reported in the above survey. We found that 55.1% of individuals had hypertension, and the National Health and Nutrition Survey reported a 40% prevalence of undiagnosed cases.²

Our results confirm that screening is useful for detecting people with NCDs. Still, the mean time between screening and the first visit to the corresponding PHC was more than 1 year. However, this time frame may be somewhat overestimated because some patients screened by MIDO may begin treatment in institutions that are not interconnected with MIDO, and thus do not share such data. On the other hand, we found that more than 90% of people diagnosed with NCDs do not attend medical visits at a PHC, a fact that is directly considered in the treatment gap. Previous analyses have reported that rates of participation in a health check among patients living with cardiometabolic diseases ranged from 1.2% to 84.1%.³¹ Early detection and treatment are essential to avoid complications, thereby saving costs for patients and for the health system.^{12 32 33}

The lack of awareness about NCD-related symptoms, risk factors and lifestyle choices is prevalent.^{34 35} Studies have found that between 30% and 35% of individuals living with T2DM were unaware of their disease.³⁶ Male sex, family history of T2DM, former smoking, overweight, obesity and lack of healthcare access are factors associated with unawareness of T2DM; our results are consistent with those of other analyses.³⁶ High T2DM unawareness increases the rate of poor metabolic control and contributes to poor management of other diseases, including hypertension.³⁷

It is crucial to investigate the reasons people do not attend a PHC once they are informed of their disease and do not attend their follow-up visits for metabolic control. Many studies have reported the following as personal barriers: socioeconomic status, lower education level, denial of illness, physical disability, patients' busy schedule and time constraints.^{38 39} Unemployment and low income, healthcare access and health services location, healthcare costs, local customs and lack of family support have been identified as economic and social barriers.³⁸ Some environmental barriers, such as health services location, transportation problems and adverse weather conditions also contribute to this problem.³⁸ Lastly, barriers related to service providers include a failure to respect patients, lack of staff, lack of patient follow-up and poor doctor-patient relationship.^{39 40} In the Mexican context, a systematic review found that the lack of economic resources, language barriers (for indigenous populations), and lack of healthcare professionals remain important barriers for patients with T2DM and hypertension in rural areas of Mexico.⁴¹

In the present analysis of disease profiles, we found that more than half of the population had predisease (pre-T2DM, prehypertension or overweight) and more than 35% had a disease (T2DM, hypertension, obesity or dyslipidaemia); only a quarter of the screened population was negative for any of the NCDs screened. The disease

profiles observed here were not surprising as Mexico has one of the highest rates of obesity worldwide (36% in 2018).⁴² As expected, comorbidities are common, especially in older populations. It has been shown that 10% and 24% of individuals with obesity have either high fasting blood glucose levels (>126 mg/dL) or undiagnosed hypertension, respectively.⁴³ Unfortunately, there is a lack of information about predisease and the prevalence of comorbidities in the Mexican population; one previous study in a younger population (age 18–30 years) reported results similar to our findings for pre-T2DM, with a prevalence of 14.6%.⁴⁴

Implications for health systems

Complementary to MIDO, the Mexican government and the main health systems implemented other strategies to prevent and control NCDs, including the national strategy 'Check yourself, measure yourself, move yourself' (a mass media campaign launched in 2013) and the 'PREVENIMSS' programme. The former was evaluated in 2016, and although the majority of the population (57.4%) recognised the campaign and its main components,⁴⁵ it was cancelled after reports showed deficits in the implementation and lack of results.¹¹ PREVENIMSS was incorporated as a primary care-based integrated programme in one of the largest healthcare providers (the Mexican Institute of Social Security (IMSS)) in 2002. The aim of PREVENIMSS was to reduce the burden of disease through preventative services and education, yet the evaluation of the impact of this programme revealed increases in rates of T2DM and hypertension. The only positive impact found was a reduction in mortality rates for cervical and breast cancers; this was associated with early detection and treatment.¹⁰ In the present analysis, we show that the MIDO screening strategy contributes to the betterment of public health by identifying predisease states of the most common NCDs and thereby allowing early intervention, particularly in disadvantaged populations lacking healthcare access. The positive results of MIDO arise from the combination of best practices, simple and accessible screening tests, and accessibility for the public (in and out of PHC settings).

From the perspective of health systems, it is well documented that an early diagnosis of T2DM will reduce the costs related to complications.^{33 46} There is a large diagnosis gap and gap from treatment to control in the case of dyslipidaemia because diagnosis and monitoring are dependent on a laboratory test. Resource investment here is crucial because it has been shown that reductions in LDL cholesterol reduce the incidence of heart attack and stroke.⁴⁷

A policy for early NCD identification should include a reliable and low-cost screening test, evidence of the benefits and costs of screening, and the capacity of the health system to identify and then manage the new burden of cases.⁴⁸ In this sense, since 2010, the Mexican health normative standards recognise the importance of screening for prediagnosis and early diagnosis of T2DM,

in people as young as 20 years old and with a screening frequency of every 3 years, especially in populations with obesity and with first-degree relatives diagnosed with the disease.⁴⁹ Our analysis showed that half of the screened population was younger than 40 years old, which is alarming as many people in this age group already have NCDs and comorbidities.

The present analysis represents a first report of identified gaps in the continuum of care after the implementation of MIDO in Mexico. The largest gap in the continuum of care is that obesity has not yet been recognised by the population as a disease, even though it is highly associated with other diseases; moreover, management of obesity through weight reduction is not a treatment commonly prioritised by health professionals.

Patients who received treatment for T2DM in CASALUD PHCs were 32% more likely to achieve disease control than patients treated at non-CASALUD PHCs. This striking difference suggests that it is possible to implement improvements in strategies focused on identification, management and control of NCDs at the first level of healthcare in Mexico. Furthermore, this has become highly relevant during the COVID-19 pandemic, as diabetes and uncontrolled blood glucose have been reported as predictors of severity and mortality in COVID-19 patients.^{50 51} It is well recognised that poor glycaemic control and insulin resistance are associated with deficits in immunological function, promoting inflammatory processes that contribute to mechanisms leading to higher risk of infections and worse outcomes in patients with T2DM.^{52 53}

Limitations

The results presented here cannot be used as an estimation of the prevalence of NCDs, mainly owing to selection bias. First, MIDO is not representative of the general Mexican population; therefore, the results cannot be extrapolated to all Mexican health systems, even though this study encompassed a large sample size representing the population without healthcare coverage in most Mexican states. Because individuals were screened in PHC facilities, a selection bias may also exist whereby individuals who have a greater likelihood of using health services (as patients or as caregivers) are also those with the highest propensity to be screened, as observed in the distribution according to sex (mainly women). We also recognise possible limitations in the estimation of gaps in the continuum of care, particularly related to data quality and missing data when linking individuals screened using MIDO with the individual administrative PHC database, SIC.⁵⁴

It is necessary to recognise that gold standard tests for diagnosing T2DM, namely, fasting plasma glucose and oral glucose tolerance tests, are not used in MIDO.¹⁹ However, the tests used in screening were fasting CG and random CG. This approach is accessible, simple and reliable for identifying undiagnosed diabetes; additionally, it

has been demonstrated that this strategy can be used to accurately predict diabetes.²⁸

CONCLUSION

Our study findings reveal that there is an urgent need to improve screening, access and retention in care for people living with NCDs in Mexico. Because comorbidities are common in this population at the time of screening and diagnosis, a patient-centred screening strategy, such as MIDO, and improved healthcare services are needed to achieve effective prevention and management of these diseases.

Author affiliations

¹Health Sciences University Center (CUCS-UdeG), University of Guadalajara, Guadalajara, Jalisco, México

²Carlos Slim Foundation, México City, Mexico

³London School of Hygiene & Tropical Medicine, London, UK

⁴Institute for Health Metrics and Evaluation, University of Washington, Seattle, Washington, USA

⁵School of Medicine, National Autonomous University of Mexico, Mexico City, Mexico

Acknowledgements We would like to thank the personnel of the Ministry of Health of Mexico (National and Local) who facilitated this project's approval and implementation, as well as helped to coordinate with local systems and study clinics. We also thank Analisa Avila, of Edanz Pharma, for providing editorial support.

Contributors AM and RSM conceived of and designed the study, acquired and interpreted the data, drafted the manuscript and revised the manuscript for important intellectual content. HGR and RTC conceived of and designed the study, acquired the data and revised the manuscript for important intellectual content. AM, LSI, LAMJ and CR acquired, analysed and interpreted the data and contributed to writing sections of the manuscript dealing with data analysis. RSM and RL conceived and designed the study and revised the manuscript for important intellectual content. All authors read and approved of the final version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding The MIDO strategy was developed and funded by the Carlos Slim Foundation; however, the present study did not receive funding from any third party agency, and there is no award or grant number to report.

Competing interests The authors HGR, AM, RSM, RMR, LSI, LAMJ and RTC are employed by the Carlos Slim Foundation in Mexico, the developer of MIDO and MIDO Plus. RTC is also affiliated with the School of Medicine of the National Autonomous University of Mexico (UNAM). CR and RL received compensation from the Carlos Slim Foundation for their contributions to this study and the manuscript. The authors declare that no other outside funding was received from any other organisations and declare no further conflicts of interest.

Patient consent for publication Not required.

Ethics approval Permission to use the deidentified patient data was granted by the Mexican Ministry of Health, in accordance with an agreement signed with the Carlos Slim Foundation.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. The data used in this study are available on reasonable request from the corresponding author.

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iD

Alejandra Montoya <http://orcid.org/0000-0002-9466-8452>

REFERENCES

- Institute for Health Metrics and Evaluation. Mexico, country profile, 2017. Available: <http://www.healthdata.org/mexico> and <http://www.healthdata.org/information-data-availability-gbd-2019>
- Campos-Nonato I, Hernández-Barrera L, Pedroza-Tobías A, *et al.* [Hypertension in Mexican adults: prevalence, diagnosis and type of treatment. *ensanut MC* 2016.]. *Salud Publica Mex* 2018;60:233–43.
- Basto-Abreu A, Barrientos-Gutiérrez T, Rojas-Martínez R, *et al.* [Prevalence of diabetes and poor glycemic control in Mexico: results from *ensanut* 2016.]. *Salud Publica Mex* 2020;62:50–9.
- Hernández-Alcaraz C, Aguilar-Salinas CA, Mendoza-Herrera K, *et al.* Dyslipidemia prevalence, awareness, treatment and control in Mexico: results of the *ensanut* 2012. *Salud Publica Mex* 2020;62:137–46.
- Iglay K, Hannachi H, Joseph Howie P, *et al.* Prevalence and co-prevalence of comorbidities among patients with type 2 diabetes mellitus. *Curr Med Res Opin* 2016;32:1243–52.
- Sumin AN, Korok EV, Shcheglova AV, *et al.* Comorbidities in patients with ischemic heart disease: gender differences. *Racional/naâ farmakoterapiâ v kardiologii* 2017;13:622–9.
- Metra M, Zacà V, Parati G, *et al.* Cardiovascular and noncardiovascular comorbidities in patients with chronic heart failure. *J Cardiovasc Med* 2011;12:76–84.
- Cortaredona S, Ventelou B. The extra cost of comorbidity: multiple illnesses and the economic burden of non-communicable diseases. *BMC Med* 2017;15:216.
- Aceves B, Ingram M, Nieto C, *et al.* Non-communicable disease prevention in Mexico: policies, programs and regulations. *Health Promot Int* 2020;35:409–21.
- Borja-Aburto VH, González-Anaya JA, Dávila-Torres J, *et al.* Evaluation of the impact on non-communicable chronic diseases of a major integrated primary health care program in Mexico. *Fam Pract* 2016;33:219–25.
- Salazar-Coronel AA, Martínez-Tapia B, Mundo-Rosas V, *et al.* Conocimiento y nivel de comprensión de la campaña chécate, mídete, muévete en adultos mexicanos. *Salud Publica Mex* 2018;60:356–64.
- Ambady R, Chamukuttan S. Early diagnosis and prevention of diabetes in developing countries. *Rev Endocr Metab Disord* 2008;9:193–201.
- Harris MI, Eastman RC. Early detection of undiagnosed diabetes mellitus: a US perspective. *Diabetes Metab Res Rev* 2000;16:230–6.
- Institute of Medicine, The Health Care Delivery System. *The future of the public's health in the 21st century*. Washington DC: National Academies Press, 2002.
- Tapia-Conyer R, Gallardo-Rincón H, Saucedo-Martínez R. CASALUD: an innovative health-care system to control and prevent non-communicable diseases in Mexico. *Perspect Public Health* 2015;135:180–90.
- Tapia-Conyer R, Saucedo-Martínez R, Mújica-Rosales R, *et al.* A policy analysis on the proactive prevention of chronic disease: learnings from the initial implementation of integrated measurement for early detection (MIDO). *Int J Health Policy Manag* 2017;6:339–44.
- Tapia-Conyer R, Gallardo-Rincón H, Saucedo-Martínez R. [Casalud: innovations for the transformation of health systems]. *Gac Med Mex* 2012;148:567–71.
- Lindström J, Tuomilehto J. The diabetes risk score: a practical tool to predict type 2 diabetes risk. *Diabetes Care* 2003;26:725–31.
- American Diabetes Association. 2. Classification and diagnosis of diabetes: *standards of medical care in diabetes-2018*. *Diabetes Care* 2018;41:S13–27.
- Chobanian AV, Bakris GL, Black HR, *et al.* Seventh report of the joint national committee on prevention, detection, evaluation, and treatment of high blood pressure. *Hypertension* 2003;42:1206–52.
- World Health Organization. Fact sheet: obesity and overweight: world health organization, 2020. Available: <https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight>
- Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults. Executive summary of the third report of the national cholesterol education program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III). *JAMA* 2001;285:2486–97.
- American Diabetes Association. 6. Glycemic targets: *standards of medical care in diabetes-2018*. *Diabetes Care* 2018;41:S55–64.
- American Diabetes Association. Postprandial blood glucose. *Diabetes Care* 2001;24:775–8.
- Chobanian AV, Bakris GL, Black HR, *et al.* The seventh report of the joint National Committee on prevention, detection, evaluation, and treatment of high blood pressure: the JNC 7 report. *JAMA* 2003;289:2560–72.
- Klein S, Allison DB, Heymsfield SB, *et al.* Waist circumference and cardiometabolic risk: a consensus statement from shaping america's health: association for weight management and obesity prevention; NAASO, the obesity society; the american society for nutrition; and the american diabetes association*. *Obesity* 2007;15:1061–7.
- Stata. *Statistical Software [program]*. College Station, TX: StataCorp LLC, 2017.
- Ritchie GE, Kengne AP, Joshi R, *et al.* Comparison of near-patient capillary glucose measurement and a risk assessment questionnaire in screening for type 2 diabetes in a high-risk population in rural India. *Diabetes Care* 2011;34:44–9.
- Briney JS, Brown EC, Hawkins JD, *et al.* Predictive validity of established cut points for risk and protective factor scales from the communities that care youth survey. *J Prim Prev* 2012;33:249–58.
- World Health Organization. Tracking universal health coverage: first global monitoring report: world health organisation, 2015. Available: https://www.who.int/healthinfo/universal_health_coverage/report/2015/en/
- de Waard A-KM, Wändell PE, Holzmann MJ, *et al.* Barriers and facilitators to participation in a health check for cardiometabolic diseases in primary care: a systematic review. *Eur J Prev Cardiol* 2018;25:1326–40.
- Clark CM, Fradkin JE, Hiss RG, *et al.* Promoting early diagnosis and treatment of type 2 diabetes: the national diabetes education program. *JAMA* 2000;284:363–5.
- Li R, Zhang P, Barker LE, *et al.* Cost-Effectiveness of interventions to prevent and control diabetes mellitus: a systematic review. *Diabetes Care* 2010;33:1872–94.
- Gyawali B, Hansen MRH, Povlsen MB, *et al.* Awareness, prevalence, treatment, and control of type 2 diabetes in a semi-urban area of Nepal: findings from a cross-sectional study conducted as a part of COBIN-D trial. *PLoS One* 2018;13:e0206491.
- Kayyali R, Slater N, Sahi A, *et al.* Type 2 diabetes: how informed are the general public? A cross-sectional study investigating disease awareness and barriers to communicating knowledge in high-risk populations in London. *BMC Public Health* 2019;19:138.
- Menke A, Casagrande S, Avilés-Santa ML, *et al.* Factors associated with being unaware of having diabetes. *Diabetes Care* 2017;40:e55–6.
- Man REK, Gan AHW, Fenwick EK, *et al.* Prevalence, determinants and association of unawareness of diabetes, hypertension and hypercholesterolemia with poor disease control in a multi-ethnic Asian population without cardiovascular disease. *Popul Health Metr* 2019;17:17.
- Zgibor JC, Songer TJ. External barriers to diabetes care: addressing personal and health systems issues. *Diabetes Spectrum* 2001;14:23–8.
- Heydarabadi AB, Mehr HM, Noughaj S. Why rural diabetic patients do not attend for scheduled appointments: results of a qualitative study. *Diabetes Metab Syndr* 2017;11 Suppl 2:S989–95.
- Peel E, Parry O, Douglas M, *et al.* Diagnosis of type 2 diabetes: a qualitative analysis of patients' emotional reactions and views about information provision. *Patient Educ Couns* 2004;53:269–75.
- Carrillo-Balam G, Cantoral A, Rodríguez-Carmona Y, *et al.* Health-care coverage and access to health care in the context of type 2 diabetes and hypertension in rural Mexico: a systematic literature review. *Public Health* 2020;181:8–15.
- Instituto Nacional de Salud Pública. Encuesta nacional de salud Y nutrición: secretaría de salud, instituto nacional de estadística geográfica e informática, instituto nacional de salud pública, 2018. Available: https://ensanut.insp.mx/encuestas/ensanut2018/doctos/informes/ensanut_2018_presentacion_resultados.pdf
- Rojas-Martínez R, Aguilar-Salinas CA, Jiménez-Corona A. Prevalence of obesity and metabolic syndrome components in Mexican adults without type 2 diabetes or hypertension. *Salud Publica Mex* 2012;54:7–12.



- 44 Ureña-Bogarín EL, Martínez-Ramírez HR, Torres-Sánchez JR, *et al.* Prevalence of pre-diabetes in young Mexican adults in primary health care. *Fam Pract* 2015;32:159–64.
- 45 Instituto Nacional de Salud Pública. Encuesta nacional de salud y nutrición de medio camino 2016, 2016. Available: <https://ensanut.insp.mx/encuestas/ensanut2016/index.php>
- 46 Gaede P, Valentine WJ, Palmer AJ, *et al.* Cost-effectiveness of intensified versus conventional multifactorial intervention in type 2 diabetes: results and projections from the steno-2 study. *Diabetes Care* 2008;31:1510–5.
- 47 Cholesterol Treatment Trialists' (CTT) Collaboration, Baigent C, Blackwell L, *et al.* Efficacy and safety of more intensive lowering of LDL cholesterol: a meta-analysis of data from 170,000 participants in 26 randomised trials. *Lancet* 2010;376:1670–81.
- 48 Narayan KMV, Chan J, Mohan V. Early identification of type 2 diabetes: policy should be aligned with health systems strengthening. *Diabetes Care* 2011;34:244–6.
- 49 Secretaría de Salud. Norma para La prevención, tratamiento Y control de la diabetes mellitus, 2010. Available: <http://www.dof.gob.mx/normasOficiales/4215/salud/salud.htm>
- 50 Bello-Chavolla OY, Bahena-López JP, Antonio-Villa NE, *et al.* Predicting mortality due to SARS-CoV-2: a mechanistic score relating obesity and diabetes to COVID-19 outcomes in Mexico. *J Clin Endocrinol Metab* 2020;105:2752–61.
- 51 Bello-Chavolla OY, González-Díaz A, Antonio-Villa NE. Unequal impact of structural health determinants and comorbidity on COVID-19 severity and lethality in older Mexican adults: looking beyond chronological aging, 2020. Available: <https://www.medrxiv.org/content/10.1101/2020.05.12.20098699v1>
- 52 Knapp S. Diabetes and infection: is there a link?--A mini-review. *Gerontology* 2013;59:99–104.
- 53 Petrie JR, Guzik TJ, Touyz RM, Diabetes TRM. Diabetes, hypertension, and cardiovascular disease: clinical insights and vascular mechanisms. *Can J Cardiol* 2018;34:575–84.
- 54 Harron K, Dibben C, Boyd J, *et al.* Challenges in administrative data linkage for research. *Big Data Soc* 2017;4:205395171774567.