

Prevalence and Population Burden of Cardiovascular–Kidney–Metabolic Syndrome Stages Among Mexican Adults: A Nationally Representative Cross-Sectional Study

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Abstract

Background

The cardiovascular–kidney–metabolic (CKM) framework integrates adiposity, metabolic risk factors, kidney disease, and cardiovascular disease into progressive stages. However, the national distribution and population burden of CKM stages in Mexico are unknown. We estimated the prevalence and corresponding population size of each CKM stage among Mexican adults.

Methods

We conducted a cross-sectional analysis of the 2018–2019 Mexican National Health and Nutrition Survey. The analytical sample included 10,522 adults aged ≥ 20 years from the fasting serum subsample. Participants were classified into mutually exclusive CKM stages 0–4 using a hierarchical algorithm based on the current CKM staging framework and adapted to the survey variables available. Classification incorporated anthropometry, glycaemia, blood pressure, lipids, estimated glomerular filtration rate, PREVENT-CVD risk, and self-reported clinical cardiovascular disease. Survey weights were recalibrated to national population margins, and design-based prevalence estimates, 95% confidence intervals, and population counts were calculated.

Results

The analytical sample represented 82.16 million Mexican adults. Stage 2 was the most prevalent category, affecting 60.8% (95% CI 59.2–62.4%), or approximately 49.95 million adults. The prevalences of stages 0, 1, 3, and 4 were 10.4%, 21.3%, 3.7%, and 3.8%, respectively. Overall, 89.6% (95% CI 88.5–90.6%), representing 73.58 million adults, met criteria for CKM stages 1–4, while advanced CKM syndrome (stages 3–4) affected 7.5% (6.6–8.3%), or 6.13 million. Among adults aged 20–44 years, 83.7% had CKM stages 1–4 and 54.1% were already in stage 2. Allowing triglycerides ≥ 150 mg/dL to independently qualify for stage 2 increased its prevalence to 69.1%, whereas the prevalence of any CKM syndrome increased more modestly to 91.8%.

Conclusions

Nearly nine in ten Mexican adults met criteria for CKM syndrome, with the burden concentrated in stage 2 and already evident in early adulthood. These estimates identify substantial population needs for integrated metabolic, kidney, and cardiovascular prevention and provide a national baseline for CKM surveillance and health-system planning in Mexico.

1. Introduction

Cardiovascular, kidney, and metabolic disorders are closely interconnected through shared biological pathways, risk factors, and social determinants. Excess or dysfunctional adiposity promotes metabolic dysfunction and contributes to cardiovascular and kidney injury, while cardiovascular and kidney disease can reciprocally reinforce one another, increasing morbidity and mortality across the cardiovascular-kidney-metabolic (CKM) continuum.[1, 2] The accumulation of these conditions may therefore have consequences that are not fully captured when obesity, metabolic abnormalities, kidney disease, and cardiovascular disease are evaluated separately. This cumulative burden is relevant not only to survival and cardiovascular outcomes but also to patients' health-related quality of life.[3]

The CKM health framework was developed to capture these interrelationships across a continuum extending from preserved health to established cardiovascular disease.[1] It classifies individuals into five mutually exclusive stages according to their most advanced manifestation: stage 0, absence of CKM risk factors; stage 1, excess or dysfunctional adiposity; stage 2, metabolic risk factors or moderate-to-high-risk chronic kidney disease; stage 3, subclinical cardiovascular disease or an equivalent high-risk state; and stage 4, clinical cardiovascular disease. Rather than replacing disease-specific diagnoses or established risk-prediction models, this framework provides an integrated approach for identifying the accumulation and progression of conditions that jointly influence cardiovascular and renal prognosis. It may therefore be particularly useful for population surveillance, prevention planning, and identification of opportunities for intervention across the life course.

Applications of the CKM framework to nationally representative surveys have shown that a high proportion of adults are already situated within the CKM continuum, although reported stage distributions vary according to population characteristics and the availability of clinical and risk-prediction variables.[4] Longitudinal studies have also demonstrated progressively higher cardiovascular and mortality risk across advanced CKM stages, with the clearest prognostic separation generally emerging between stages 1 and 2 and becoming more pronounced at stages 3 and 4.[5–7] These findings support the use of CKM staging as a descriptive surveillance and broad prognostic-stratification framework, while its role as a stand-alone individual prediction instrument remains less established.

This integrated perspective is particularly relevant in Mexico. According to Global Burden of Disease Study 2023 estimates, cardiovascular diseases and the combined category of diabetes and kidney diseases were the two leading disease groups contributing to disability-adjusted life-years among Mexican adults aged 20 years or older.[8] National studies have also documented a high prevalence of overweight/obesity, metabolic syndrome, chronic kidney disease (CKD), and cardiometabolic multimorbidity. Analyses of the Mexican National Health and Nutrition Survey (*Encuesta Nacional de Salud y Nutrición* [ENSANUT]) reported that metabolic syndrome prevalence reached approximately 56% in 2018, while other ENSANUT-based studies identified substantial burdens of albuminuria, reduced kidney function, and combinations of diabetes, hypertension, obesity, and cardiovascular disease.[9–11] Nevertheless, these metabolic, kidney, and cardiovascular components have generally been examined separately or as overlapping multimorbidity patterns rather than as mutually exclusive stages encompassing the complete CKM continuum.

Therefore, this study aimed to estimate the prevalence and national population size of operational CKM stages among Mexican adults using ENSANUT 2018–2019 data. We additionally examined stage distributions by age and sex, characterized the clinical and metabolic profiles of each stage, compared the population burden identified by CKM staging with that identified by metabolic syndrome, and assessed the robustness of the estimates across alternative operational definitions and survey-weighting specifications.

2. Methods

2.1 Study design and data source

We conducted a cross-sectional secondary analysis of the ENSANUT 2018–2019, a probabilistic, multistage, stratified, and clustered household survey designed to generate nationally representative health and nutrition estimates for the Mexican population.[12] Fieldwork was conducted between July 2018 and June 2019. The survey contains information from 44,069 homes and 82,490 complete interviews.

We used information from the adult health questionnaire, anthropometric and blood pressure assessments, and the fasting biochemical subsample. Records were linked across survey components using unique household and participant identifiers, with consistency checks for age, sex, sampling stratum, and primary sampling unit.

This study was a secondary analysis of publicly available, deidentified ENSANUT 2018–19 microdata. The original survey protocol was approved by the Ethics, Research, and Biosafety Committees of the National Institute of Public Health of Mexico, and all participants provided written informed consent.

2.2 Study population

The study population comprised nonpregnant adults aged 20 years or older who participated in the fasting serum subsample. Participants were eligible if they had fasted for 8–24 hours and had valid blood pressure, weight, height, waist circumference, fasting glucose, triglyceride, high-density lipoprotein cholesterol (HDL-C), total cholesterol, and serum creatinine data.

Standard plausibility criteria were applied to anthropometric measurements (height $\geq$ 130 cm, waist circumference 50–200 cm, and BMI 10–58 kg/m²). The final analytical sample comprised 10,522 nonpregnant adults (Supplementary Figure S1).

2.3 Measurements and clinical definitions

Weight, height, waist circumference, and blood pressure were measured by trained personnel using standardized ENSANUT procedures. When replicate measurements were available, their mean was used. [12]

BMI was calculated as weight in kilograms divided by height in meters squared. Overweight or obesity was defined as BMI ≥ 25 kg/m² and obesity as BMI ≥ 30 kg/m². Abdominal adiposity was defined as waist circumference ≥ 80 cm in women or ≥ 90 cm in men, using population-specific thresholds recommended for Central and South American populations.[13] Alternative thresholds of ≥ 88 cm in women and ≥ 102 cm in men were examined in sensitivity analysis.[14]

Hypertension, diabetes, prediabetes, hypertriglyceridaemia, and low HDL-C were identified from standardized measurements, self-reported physician diagnosis, and medication use, as applicable, using established criteria [13, 14] (Table 1). Metabolic syndrome was defined as the presence of at least three of five harmonized components: abdominal adiposity; triglycerides ≥ 150 mg/dL; low HDL-C; systolic blood pressure ≥ 130 mmHg, diastolic blood pressure ≥ 85 mmHg, or antihypertensive treatment; and fasting glucose ≥ 100 mg/dL, diagnosed diabetes, or glucose-lowering treatment.[14] Metabolic syndrome contributed to stage 2 classification and was retained as a limited descriptive comparator at the overall population level.

2.4 Kidney function and cardiovascular disease

Estimated glomerular filtration rate (eGFR) was calculated using the 2021 race-free CKD-EPI creatinine equation.[15] Because urine albumin-to-creatinine ratio was unavailable and serum creatinine was measured once, impaired renal function was interpreted as a kidney-risk proxy rather than confirmed CKD. An eGFR of 30–59 mL/min/1.73 m² denoted moderate kidney risk, eGFR < 30 mL/min/1.73 m² denoted very high kidney risk, and kidney failure was defined as eGFR < 15 mL/min/1.73 m² or self-reported dialysis or haemodialysis.[1, 16]

Table 1
CKM staging framework and study-specific operational definitions

Stage	CKM framework	Operational definition used in the present analysis	Principal study-specific adaptation or limitation
Operational stage 0	No CKM risk factors: normal adiposity, glycaemia, blood pressure, lipids, and kidney function; no subclinical or clinical CVD.	Absence of every qualifying criterion for stages 1–4.	Defined by exclusion. Isolated triglycerides ≥ 150 mg/dL or low HDL-C did not increase stage.
Stage 1	Excess or dysfunctional adiposity without other metabolic risk factors or CKD.	BMI ≥ 25 kg/m ² , waist ≥ 80 cm in women or ≥ 90 cm in men, or prediabetes, without criteria for stages 2–4.	Population-specific waist thresholds were used; $\geq 88/102$ cm was examined in sensitivity analysis.
Stage 2	Metabolic risk factors or moderate-to-high kidney risk without stage 3 or 4 criteria.	Hypertension, diabetes, harmonized metabolic syndrome, or eGFR 30–59 mL/min/1.73 m ² .	Triglycerides and low HDL-C qualified only within metabolic syndrome. UACR was unavailable; eGFR was measured once.
Stage 3	Subclinical CVD or a cardiovascular-risk equivalent without clinical CVD.	eGFR < 30 mL/min/1.73 m ² or PREVENT-CVD 10-year total CVD risk $\geq 20\%$ among adults aged 30–79 years.	No direct subclinical CVD tests or UACR were available. PREVENT-CVD was restricted to validated ages and predictor ranges.
Stage 4	Clinical coronary heart disease, heart failure, stroke, peripheral artery disease, or atrial fibrillation.	Self-reported physician-diagnosed myocardial infarction, angina, heart failure, or stroke.	Peripheral artery disease and atrial fibrillation were unavailable. Stages 4a and 4b were not reported separately.
Assignment rule	Individuals may meet criteria for more than one stage.	Stages were assigned hierarchically from stage 4 to stage 0; the highest qualifying stage prevailed.	Current adiposity was not required for assignment to stages 2–4.

Note: Hypertension was defined as blood pressure $\geq 130/80$ mmHg or antihypertensive treatment; diabetes as self-reported physician diagnosis, glucose-lowering medication use, fasting glucose ≥ 126 mg/dL, or HbA1c $\geq 6.5\%$, when available; and prediabetes as fasting glucose 100–125 mg/dL or HbA1c 5.7–6.4% in participants without diabetes. Metabolic syndrome required at least three harmonized components: increased waist circumference (≥ 80 cm in women or ≥ 90 cm in men), triglycerides ≥ 150 mg/dL, low HDL-C (< 50 mg/dL in women or < 40 mg/dL in men), blood pressure $\geq 130/85$ mmHg or antihypertensive treatment, and fasting glucose ≥ 100 mg/dL or glucose-lowering treatment [13, 14]. CKD=chronic kidney disease; CKM=cardiovascular–kidney–metabolic; CVD=cardiovascular disease; eGFR=estimated glomerular filtration rate; HbA1c=glycated haemoglobin; HDL-C=high-density

lipoprotein cholesterol; PREVENT=Predicting Risk of Cardiovascular Disease EVENTS; UACR=urine albumin-to-creatinine ratio.

Clinical cardiovascular disease was identified from affirmative self-reports of physician-diagnosed myocardial infarction, angina, heart failure, or stroke. Missing responses to conditional cardiovascular questions were not treated as affirmative diagnoses. Clinical CVD definitions and unavailable conditions are summarized in Table 1; a stage 4 definition restricted to myocardial infarction or stroke was examined in sensitivity analysis (Supplementary Table S2).

Among adults aged 30–79 years without clinical CVD, 10-year total CVD risk was estimated using the published sex-specific base PREVENT-CVD equations [17]. PREVENT-CVD was selected because it is specified in the CKM staging framework, incorporates eGFR, and estimates both atherosclerotic CVD and heart failure; a predicted risk $\geq 20\%$ qualified for stage 3. Primary estimates were limited to the validated age and predictor ranges, with truncation to the nearest predictor boundary examined in sensitivity analysis.

2.5 Operational CKM staging

Participants were assigned to mutually exclusive cardiovascular–kidney–metabolic (CKM) stages using a descending hierarchical algorithm in which the highest qualifying stage prevailed (Table 1 and Fig. 1). The conceptual staging framework was based on the 2026 multisociety guideline for the prevention, detection, evaluation, and management of CKM [1].

- Stage 4: self-reported clinical cardiovascular disease;
- Stage 3: eGFR < 30 mL/min/1.73 m² or PREVENT-CVD 10-year risk $\geq 20\%$, in the absence of stage 4;
- Stage 2: hypertension, diabetes, metabolic syndrome, or eGFR of 30–59 mL/min/1.73 m², in the absence of stages 3–4;
- Stage 1: overweight or obesity, abdominal adiposity, or prediabetes, in the absence of stages 2–4; and
- Operational stage 0: absence of any qualifying criterion for stages 1–4.

Note

Percentages are weighted national prevalence estimates among nonpregnant Mexican adults aged ≥ 20 years. Participants were assigned hierarchically to their highest qualifying CKM stage. The study-specific operational definitions reflect the variables available in ENSANUT 2018–19. ^a Under the alternative specification allowing fasting triglycerides ≥ 150 mg/dL to independently qualify for stage 2, the prevalences of stage 2 and CKM stages 1–4 were 69.1% and 91.8%, respectively. The complete alternative stage distribution is provided in Supplementary Table S3.

AF=atrial fibrillation; BMI=body mass index; CKM=cardiovascular–kidney–metabolic; CVD=cardiovascular disease; eGFR=estimated glomerular filtration rate; HDL-C=high-density lipoprotein

cholesterol; MI=myocardial infarction; PAD=peripheral artery disease; PREVENT=Predicting Risk of Cardiovascular Disease EVENTS; UACR=urine albumin-to-creatinine ratio.

Current adiposity was not required for assignment to stages 2–4 because established metabolic, kidney, or cardiovascular disease may persist after intentional or disease-related weight loss. This was a study-specific operational decision. In the main study-specific operational definition, hypertriglyceridaemia and low HDL-C contributed to stage 2 through metabolic syndrome but did not independently advance CKM stage. Because hypertriglyceridaemia is listed among the metabolic risk factors within the CKM framework, we additionally estimated an alternative specification in which fasting triglycerides ≥ 150 mg/dL independently qualified for stage 2.

Direct measures of coronary atherosclerosis, pre-heart failure, albuminuria, peripheral artery disease, and atrial fibrillation were unavailable. Accordingly, stages 2–4, particularly stage 3, represent conservative operational estimates based on the criteria observable in ENSANUT.

2.6 Statistical analysis

All analyses accounted for survey strata, primary sampling units (PSUs), and weights. Because complete-case restriction altered the population distribution represented by the official fasting-glucose subsample weight, weights were recalibrated by iterative proportional fitting to the nonpregnant adult ENSANUT population using age group by sex and region by urban or rural residence as margins. Estimates represent nonpregnant Mexican adults aged ≥ 20 years [12, 18].

We estimated weighted prevalence, unweighted sample sizes, 95% confidence intervals, and affected populations in millions for CKM stages 0–4, overall and by sex and age group (20–44, 45–64, and ≥ 65 years). Estimates by 10-year age group and sex are reported in Supplementary Table S1. We also estimated any CKM syndrome (stages 1–4), CKM stages 2–4, advanced CKM syndrome (stages 3–4), and metabolic syndrome. Metabolic syndrome served only as an overall descriptive comparator with any CKM syndrome and CKM stages 2–4. Stage characteristics were summarized as weighted proportions or means with 95% confidence intervals. Among PREVENT-CVD-eligible adults, 10-year risk was summarized by weighted median and interquartile range and by weighted proportions in the $< 5\%$, $5\text{--}<10\%$, $10\text{--}<20\%$, and $\geq 20\%$ categories.

Standard errors were estimated by Taylor series linearization; single-PSU strata used a conservative adjustment centered on the grand PSU mean. Sensitivity analyses examined triglycerides as an independent stage 2 criterion, alternative waist thresholds, PREVENT-CVD predictor-boundary truncation, the restricted CVD definition, and original versus recalibrated weights (Supplementary Table S3).

Analyses were descriptive, without adjustment for multiple comparisons. Reconstruction and validation used reproducible Python 3.12 scripts based on pandas and NumPy; a parallel R workflow was prepared to independently reproduce the tables and figures. Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.

2.7 Use of generative artificial intelligence

OpenAI ChatGPT and Codex were used to assist with the development and review of analytical and figure-generation code, consistency checking, and English-language editing. These tools did not generate study data or independently determine analytical definitions, methods, results, or conclusions. All code, outputs, figures, and manuscript text were reviewed and verified by the authors, who retain full responsibility for the work.

3. Results

3.1 Participant selection and weighted population

Among 43,070 records in the adult questionnaire, 13,162 participants were included in the fasting serum subsample with an assigned glucose-subsample weight. After sequential exclusions for fasting duration, blood pressure availability, pregnancy, incomplete or implausible anthropometric measurements, and missing core biomarkers, the final analytical sample comprised 10,522 adults, including 6,005 women and 4,517 men (Supplementary Figure S1). After weight recalibration, the sample represented 82.16 million nonpregnant Mexican adults aged 20 years or older, of whom 54.3% were women.

3.2 Overall distribution of CKM stages

Under the main study-specific operational definition, stage 2 was the most prevalent CKM category, affecting 60.8% (95% CI 59.2–62.4%) of adults, corresponding to an estimated 49.95 million people (Table 2). When fasting triglycerides ≥ 150 mg/dL were alternatively treated as an independent stage 2 criterion, its prevalence was 69.1%. Overall, 89.6% (95% CI 88.5–90.6%), representing 73.58 million adults, met criteria for CKM stages 1–4 under the main definition, compared with 91.8% under the alternative triglyceride specification.

Stage 1 affected 21.3% (20.0–22.6%; 17.50 million), whereas 10.4% (9.4–11.5%; 8.58 million) were classified as operational stage 0 under the main study-specific operational definition. Stage 3 accounted for 3.7% (3.0–4.3%; 3.03 million) and stage 4 for 3.8% (3.2–4.3%; 3.10 million) of the population. CKM stages 2–4 affected 68.3% (66.7–69.8%; 56.08 million), while advanced CKM syndrome, defined as stages 3–4, affected 7.5% (6.6–8.3%; 6.13 million). The prevalence of metabolic syndrome was 55.2% (53.6–56.9%; 45.39 million), 34.3 percentage points lower than that of any CKM syndrome and 13.0 percentage points lower than that of CKM stages 2–4.

3.3 CKM stages by age and sex

The distribution of CKM stages varied markedly across age groups (Fig. 2 and Supplementary Table S1). Among adults aged 20–44 years, 83.7% (95% CI 82.0–85.4%) met criteria for CKM stages 1–4. Stage 2 was already the predominant category in this age group, affecting 54.1%

Table 2
Overall CKM stage prevalence and estimated number of Mexican adults

Category	Weighted prevalence, % (95% CI)	Population, millions
Operational stage 0	10.4 (9.4–11.5)	8.58
Stage 1	21.3 (20.0–22.6)	17.50
Stage 2	60.8 (59.2–62.4) ^a	49.95
Stage 3	3.7 (3.0–4.3)	3.03
Stage 4	3.8 (3.2–4.3)	3.10
Any CKM syndrome (stages 1–4)	89.6 (88.5–90.6) ^a	73.58
CKM stages 2–4	68.3 (66.7–69.8)	56.08
Advanced CKM syndrome (stages 3–4)	7.5 (6.6–8.3)	6.13
Metabolic syndrome	55.2 (53.6–56.9)	45.39

Note: Estimates use recalibrated fasting-biochemical-subsample weights and represent nonpregnant Mexican adults aged ≥ 20 years. Mutually exclusive stage rows sum to 100%; summary categories combine constituent stages. CI=confidence interval; CKM=cardiovascular–kidney–metabolic. ^a Under the alternative specification allowing fasting triglycerides ≥ 150 mg/dL to independently qualify for stage 2, the prevalences of stage 2 and CKM stages 1–4 were 69.1% and 91.8%, respectively. The complete alternative stage distribution is provided in Supplementary Table S3.

Note

Bars show weighted national prevalence estimates. The asterisk denotes stage 3 prevalence of 0.1% among adults aged 20–44 years, for which an internal percentage label could not be displayed. Under the alternative specification allowing fasting triglycerides ≥ 150 mg/dL to independently qualify for stage 2, the prevalences of stage 2 and CKM stages 1–4 were 69.1% and 91.8%, respectively. The complete alternative stage distribution is provided in Supplementary Table S3. Percentages may not total 100% because of rounding. CKM=cardiovascular–kidney–metabolic.

(52.0–56.2%), followed by stage 1 at 27.1% (25.3–29.0%). Stage 3 was uncommon at 0.1% (0.0–0.1%), whereas stage 4 affected 2.4% (1.7–3.0%).

Among adults aged 45–64 years, the prevalence of any CKM syndrome increased to 96.0% (95.0–97.0%), and nearly three-quarters were classified as stage 2 (73.1%, 70.6–75.7%). Stage 3 and stage 4 affected 2.3% (1.3–3.3%) and 4.4% (3.4–5.4%), respectively. Among adults aged 65 years or older, 97.8% (97.0–98.6%) met criteria for CKM stages 1–4. Stage 2 remained the most frequent category at 58.8% (54.7–62.8%), while stage 3 increased substantially to 21.0% (17.8–24.2%) and stage 4 to 7.7% (6.0–9.5%).

Women had a numerically higher prevalence of any CKM syndrome than men (91.0% [95% CI 89.6–92.3%] vs 87.9% [86.1–89.6%]). Stage 1 was more frequent among women than men (24.0% vs 18.1%), whereas stage 2 prevalence was similar (60.4% vs 61.2%). Men had numerically higher prevalences of stage 3 (4.5% vs 3.0%) and stage 4 (4.0% vs 3.6%).

3.4 Population characteristics by CKM stage

Clinical and metabolic profiles differed across the mutually exclusive CKM stages (Table 3). Weighted mean age increased from 31.5 years in operational stage 0 to 38.8 years in stage 1 and 46.2 years in stage 2. Participants in stage 3 were the oldest, with a mean age of 70.3 years, whereas the mean age in stage 4 was 52.8 years.

Abdominal adiposity was present in 86.3% of adults in stage 1 and approximately 90% of those in stages 2–4. Obesity prevalence increased from 24.6% in stage 1 to 44.1% in stage 2 and was 31.1% and 42.2% in stages 3 and 4, respectively. Diabetes affected 20.2% of adults in stage 2, 62.2% in stage 3, and 29.6% in stage 4. The corresponding prevalences of hypertension were 69.3%, 86.9%, and 68.0%.

Stage 3 was characterized by the greatest measured cardiovascular and kidney-risk burden. Participants in this stage had a mean systolic blood pressure of 144.9 mmHg, a mean fasting

Table 3
Population characteristics by CKM stage

Characteristic	Type	Stage 0 (n = 891)	Stage 1 (n = 2,052)	Stage 2 (n = 6,637)	Stage 3 (n = 490)	Stage 4 (n = 452)
Women	%	46.8 (41.4–52.3)	61.1 (57.4–64.8)	54.0 (52.0–55.9)	44.2 (35.4–53.1)	52.0 (44.7–59.3)
Obesity (BMI ≥ 30 kg/m ²)	%	0.0 (0.0–0.0)	24.6 (21.5–27.7)	44.1 (42.1–46.1)	31.1 (23.4–38.8)	42.2 (35.1–49.3)
Abdominal adiposity (80/90 cm)	%	0.0 (0.0–0.0)	86.3 (83.8–88.9)	90.0 (88.8–91.3)	89.4 (86.0–92.8)	90.0 (86.3–93.7)
Prediabetes	%	0.0 (0.0–0.0)	14.3 (11.6–17.0)	24.8 (22.9–26.6)	12.4 (8.1–16.7)	20.5 (15.0–25.9)
Diabetes	%	0.0 (0.0–0.0)	0.0 (0.0–0.0)	20.2 (18.7–21.8)	62.2 (53.9–70.5)	29.6 (22.8–36.4)
Hypertension	%	0.0 (0.0–0.0)	0.0 (0.0–0.0)	69.3 (67.4–71.1)	86.9 (79.4–94.4)	68.0 (61.5–74.4)
Metabolic syndrome	%	0.0 (0.0–0.0)	0.0 (0.0–0.0)	81.1 (79.5–82.7)	83.2 (75.9–90.4)	76.5 (70.8–82.2)
eGFR < 60 mL/min/1.73 m ²	%	0.0 (0.0–0.0)	0.0 (0.0–0.0)	1.4 (1.0–1.8)	21.9 (15.7–28.1)	6.5 (3.6–9.5)
Current smoking	%	23.6 (19.0–28.2)	20.2 (17.1–23.3)	16.7 (15.1–18.3)	22.5 (16.2–28.9)	18.7 (12.6–24.8)
Age, years	Mean	31.5 (30.4–32.6)	38.8 (37.7–39.9)	46.2 (45.6–46.9)	70.3 (69.1–71.5)	52.8 (50.2–55.3)
BMI, kg/m ²	Mean	21.6 (21.4–21.8)	28.0 (27.7–28.3)	30.0 (29.8–30.2)	28.4 (27.6–29.1)	29.8 (29.1–30.6)
Waist circumference, cm	Mean	77.3 (76.7–77.9)	94.3 (93.2–95.4)	99.3 (98.8–99.8)	99.4 (97.6–101.1)	100.0 (98.4–101.5)
Systolic blood pressure, mmHg	Mean	109.9 (109.0–110.9)	111.2 (110.5–111.9)	129.2 (128.3–130.0)	144.9 (141.3–148.6)	129.6 (126.6–132.7)

Characteristic	Type	Stage 0 (n = 891)	Stage 1 (n = 2,052)	Stage 2 (n = 6,637)	Stage 3 (n = 490)	Stage 4 (n = 452)
Fasting glucose, mg/dL	Mean	82.8 (81.9– 83.7)	86.7 (86.0– 87.4)	108.2 (106.3– 110.0)	126.3 (118.0– 134.6)	110.4 (103.2– 117.5)
eGFR, mL/min/1.73 m ²	Mean	120.2 (118.9– 121.5)	114.8 (113.7– 116.0)	108.6 (107.9– 109.3)	77.1 (73.4– 80.8)	100.2 (97.0– 103.5)

Note: Categorical characteristics are weighted percentages (95% CI); continuous characteristics are weighted means (95% CI). BMI=body mass index; CI=confidence interval; CKM=cardiovascular–kidney–metabolic; eGFR=estimated glomerular filtration rate.

glucose concentration of 126.3 mg/dL, and a mean eGFR of 77.1 mL/min/1.73 m². An eGFR below 60 mL/min/1.73 m² was present in 21.9% of stage 3, compared with 1.4% of stage 2 and 6.5% of stage 4 participants.

Among 7,043 adults eligible for PREVENT-CVD estimation, the median 10-year total cardiovascular disease risk was 2.9% (interquartile range 1.2–7.9). The proportions with risks below 5%, from 5% to < 10%, from 10% to < 20%, and ≥ 20% were 63.1%, 16.6%, 14.7%, and 5.6%, respectively (Supplementary Table S2).

3.5 Sensitivity analyses

The overall prevalence of CKM syndrome was generally robust across alternative operational and weighting specifications (Supplementary Table S3). When triglycerides ≥ 150 mg/dL were allowed to independently qualify for stage 2, the prevalence increased from 60.8% to 69.1%, primarily through reclassification from stage 1. The prevalence of any CKM syndrome increased modestly, from 89.6% to 91.8%.

Truncating PREVENT-CVD predictors to their nearest validated boundaries increased stage 3 prevalence from 3.7% to 4.8% and reduced stage 2 prevalence from 60.8% to 59.7%, without changing the estimated prevalence of any CKM syndrome. Applying the alternative waist thresholds of ≥ 88 cm in women and ≥ 102 cm in men reduced the prevalence of any CKM syndrome to 86.4% and stage 2 prevalence to 56.9%.

Restricting clinical cardiovascular disease to self-reported myocardial infarction or stroke reduced stage 4 prevalence from 3.8% to 1.9%; the remaining 1.9% corresponded to participants reporting angina or heart failure without myocardial infarction or stroke. Estimates obtained using the original biochemical-subsample weights were similar to those from the recalibrated weights: the prevalence of any CKM syndrome was 89.9% versus 89.6%, metabolic syndrome 55.9% versus 55.2%, and advanced CKM syndrome 7.6% versus 7.5%, respectively.

4. Discussion

To our knowledge, this is the first nationally representative assessment of operational CKM syndrome stages among Mexican adults. Nearly nine in ten adults met criteria for stages 1–4, representing approximately 73.6 million people, while more than two-thirds were classified in stages 2–4. Stage 2 represented the largest population group, comprising nearly 50 million adults with metabolic risk factors, metabolic syndrome, or moderate kidney risk. By integrating early adiposity-related abnormalities, metabolic risk, kidney involvement, predicted cardiovascular risk, and clinical cardiovascular disease, CKM staging identified a broader spectrum of health needs than isolated diseases or metabolic syndrome alone.

The high prevalence of CKM syndrome is broadly consistent with population studies from the United States and Korea, although Mexico showed a greater concentration in stage 2 and a smaller proportion in stage 4.[4, 19] Direct numerical comparisons require caution because CKM operationalization has varied according to the availability of albuminuria, subclinical cardiovascular measurements, risk-prediction variables, age ranges, and definitions of clinical cardiovascular disease. Nevertheless, the predominance of intermediate stages across populations suggests that the greatest opportunity for prevention occurs before cardiovascular disease becomes clinically established.

Previous ENSANUT studies documented substantial burdens of metabolic syndrome, albuminuria, reduced kidney function, and cardiometabolic multimorbidity.[9–11] The present analysis extends this evidence by integrating these domains into mutually exclusive stages and translating their prevalence into national population counts. This approach complements rather than replaces disease-specific surveillance by identifying where adults are situated along a shared cardiovascular, kidney, and metabolic continuum.

The early accumulation of CKM risk was particularly concerning. Stage 2 was already the predominant category among adults aged 20–44 years and remained highly prevalent in middle age. Although cross-sectional data cannot establish individual progression, longitudinal studies have demonstrated progressively increasing cardiovascular and mortality risk across CKM stages.[5–7] Among US Hispanic/Latino adults, one in five progressed to a higher stage over six years, while only one in ten regressed.[20] The large number of young and middle-aged Mexican adults in stages 1–2 may therefore foreshadow a growing future burden unless modifiable risk is addressed early.

Stage 3 participants were older and had a greater measured burden of diabetes, hypertension, elevated systolic blood pressure, and reduced eGFR than those in stage 4. This apparent non-monotonic pattern reflects the hierarchical construction of the stages rather than lower clinical severity in stage 4. Stage 3 was driven by very high kidney risk or a PREVENT-CVD risk of at least 20%, both strongly influenced by age and accumulated comorbidity. In contrast, stage 4 was assigned from self-reported clinical cardiovascular disease, regardless of current age or metabolic profile. Thus, CKM stages represent distinct clinical states along a continuum, but individual risk factors are not expected to increase monotonically across every stage.

The use of PREVENT-CVD was intended to preserve fidelity to the current CKM staging framework rather than to establish its superiority over other cardiovascular risk equations. Its incorporation of kidney function and prediction of total cardiovascular disease, including heart failure, are conceptually aligned with the integrated CKM construct. In the multiethnic ELSA-Brasil cohort, PREVENT and the 2019 WHO risk equations showed similar discrimination, but PREVENT demonstrated better calibration and clinically relevant risk reclassification.[21] However, these findings cannot be directly extrapolated to Mexico, and comparative predictive performance could not be evaluated in ENSANUT because longitudinal cardiovascular outcomes were unavailable.

The sensitivity analyses showed that operational decisions affected stage-specific prevalence but had a smaller influence on the overall CKM burden. Allowing triglycerides ≥ 150 mg/dL to independently qualify for stage 2 increased its prevalence by 8.3 percentage points, predominantly through reclassification from stage 1, whereas the prevalence of any CKM syndrome increased by only 2.2 points. In the primary definition, hypertriglyceridaemia and low HDL-C contributed through metabolic syndrome but did not independently increase CKM stage. This decision reflected uncertainty regarding the incremental prognostic information conveyed by isolated fasting hypertriglyceridaemia after accounting for other lipid and metabolic factors, as well as evidence that risk estimates differ according to fasting status.[22, 23]

Taken together, these findings support prospective evaluation of whether an isolated fasting triglyceride concentration ≥ 150 mg/dL provides sufficient prognostic discrimination to justify its use as an independent stage 2 criterion. Alternative waist thresholds and PREVENT-CVD predictor handling also redistributed participants between stages, whereas original and recalibrated survey weights produced similar estimates. Thus, the overall burden was robust, although individual-stage prevalence remained partly dependent on available variables and operational rules.

4.1 Public Health and Healthcare Implications

The findings provide a population-health rationale for organizing prevention and care across the CKM continuum. This perspective aligns with recent Mexican efforts to mitigate the CKM burden through the National Medical Care Protocols (PRONAMs, *Protocolos Nacionales de Atención Médica*) for CKM syndrome, which promote integrated assessment and management, particularly in primary care.[24, 25] CKM staging could complement this initiative by quantifying the populations requiring different levels of prevention, diagnosis and therapeutics interventions. For adults in stage 0, the objective is to prevent excess or dysfunctional adiposity and preserve normal glycaemia, blood pressure, lipid levels, and kidney function. Stage 1 calls for preventing further adiposity-related dysfunction through healthy lifestyles and, when appropriate, effective weight-management interventions. Stage 2 represents the largest population-level challenge and requires coordinated management of diabetes, hypertension, and other metabolic risk factors, together with timely detection and treatment of kidney disease. Stage 3 requires intensified prevention of clinical cardiovascular disease, whereas stage 4 requires comprehensive

secondary prevention to reduce recurrent cardiovascular disease and optimize the management of established cardiovascular disease.[1, 26]

4.2 Strengths and Limitations

This study has several strengths. It used data from a large national health survey with a probability-based complex sampling design that, together with survey weights recalibrated to national population margins, supported nationally representative estimates for Mexican adults. Additional strengths included standardized anthropometric, blood-pressure, and biochemical measurements, as well as parallel estimates under alternative operational definitions and weighting strategies. The reproducible hierarchical staging algorithm generated both prevalence estimates and corresponding population counts relevant to health-service planning.

Some limitations merit consideration. First, the absence of albuminuria likely resulted in underestimation of moderate-to-high kidney risk and limited characterization of stages 2 and 3. Moreover, because kidney function was assessed at a single examination, impaired renal function was interpreted as a kidney-risk proxy rather than confirmed CKD. ENSANUT also lacked direct measures of subclinical coronary atherosclerosis, pre-heart failure, peripheral artery disease, and atrial fibrillation, while clinical cardiovascular disease was ascertained by self-report. PREVENT-CVD could be applied only within its eligible age range, and stage estimates were sensitive to how predictor values outside its validated boundaries were handled. Second, the complete-case restriction may have introduced selection bias. Although weight recalibration restored major demographic margins and analyses using the original subsample weights produced similar estimates, these procedures cannot eliminate bias arising from unmeasured differences between included and excluded participants. Finally, the cross-sectional design precludes inference regarding individual stage progression or the ability of these operational stages to predict clinical outcomes in Mexico.

5. Conclusions

CKM syndrome affected most Mexican adults and was already highly prevalent in young and middle-aged populations. By integrating metabolic risk, kidney status, predicted cardiovascular risk, and established disease, CKM staging identified population needs that may be obscured when these conditions are examined separately. The findings support coordinated policies and care models spanning preservation of CKM health, adiposity reduction, comprehensive metabolic risk-factor control, kidney-damage detection, cardiovascular prevention, and secondary prevention. Longitudinal studies are needed to validate the prognostic meaning of these operational stages in Mexico.

Abbreviations

AF
atrial fibrillation
BMI

body mass index
CI
confidence interval
CKD
chronic kidney disease
CKD-EPI
Chronic Kidney Disease Epidemiology Collaboration
CKM
cardiovascular–kidney–metabolic
CVD
cardiovascular disease
eGFR
estimated glomerular filtration rate
ENSANUT
Encuesta Nacional de Salud y Nutrición (Mexican National Health and Nutrition Survey)
HbA1c
glycated haemoglobin
HDL-C
high-density lipoprotein cholesterol
IQR
interquartile range
MI
myocardial infarction
PAD
peripheral artery disease
PREVENT-CVD
Predicting Risk of Cardiovascular Disease EVENTS equation for total cardiovascular disease
PRONAM
Protocolos Nacionales de Atención Médica (National Medical Care Protocols)
UACR
urine albumin-to-creatinine ratio.

Declarations

Ethics approval and consent to participate

The present study was a secondary analysis of de-identified data from the 2018–2019 Mexican National Health and Nutrition Survey. The original survey protocol and procedures were approved by the Ethics, Research, and Biosafety Committees of the National Institute of Public Health of Mexico. Written

informed consent was obtained from all participants. The present analysis involved no additional participant recruitment or contact.

Consent for publication

Not applicable.

Availability of data and materials

The de-identified public-use datasets from the 2018–2019 Mexican National Health and Nutrition Survey analysed in this study are publicly available through the National Institute of Public Health of Mexico ENSANUT repository (<https://ensanut.insp.mx/>). Machine-readable aggregate data underlying the tables and figures, together with variable-derivation documentation, are provided in Additional file 2. The study-specific analytical code is available from the corresponding author on reasonable request.

Competing interests

RST reports participation as a speaker in educational activities organized by Novo Nordisk, Lilly, and Boehringer Ingelheim. DEL reports participation as a speaker in educational activities organized by Abbott, Amgen, Lilly, MSD, Novartis, and Novo Nordisk. The remaining authors declare that they have no competing interests.

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Authors' contributions

Conceptualization: RST, AAB. Methodology: RST, AARA. Formal analysis: RST. Validation: AARA, AFH. Visualization: RST, HSZ. Interpretation: RST, AAB, AOT. Writing – original draft: RST, AAB, AOT, HECC. Writing – review and editing: AFH, DEL, HSZ. All authors critically reviewed the manuscript, approved the final version, and agreed to be accountable for the work.

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Figures

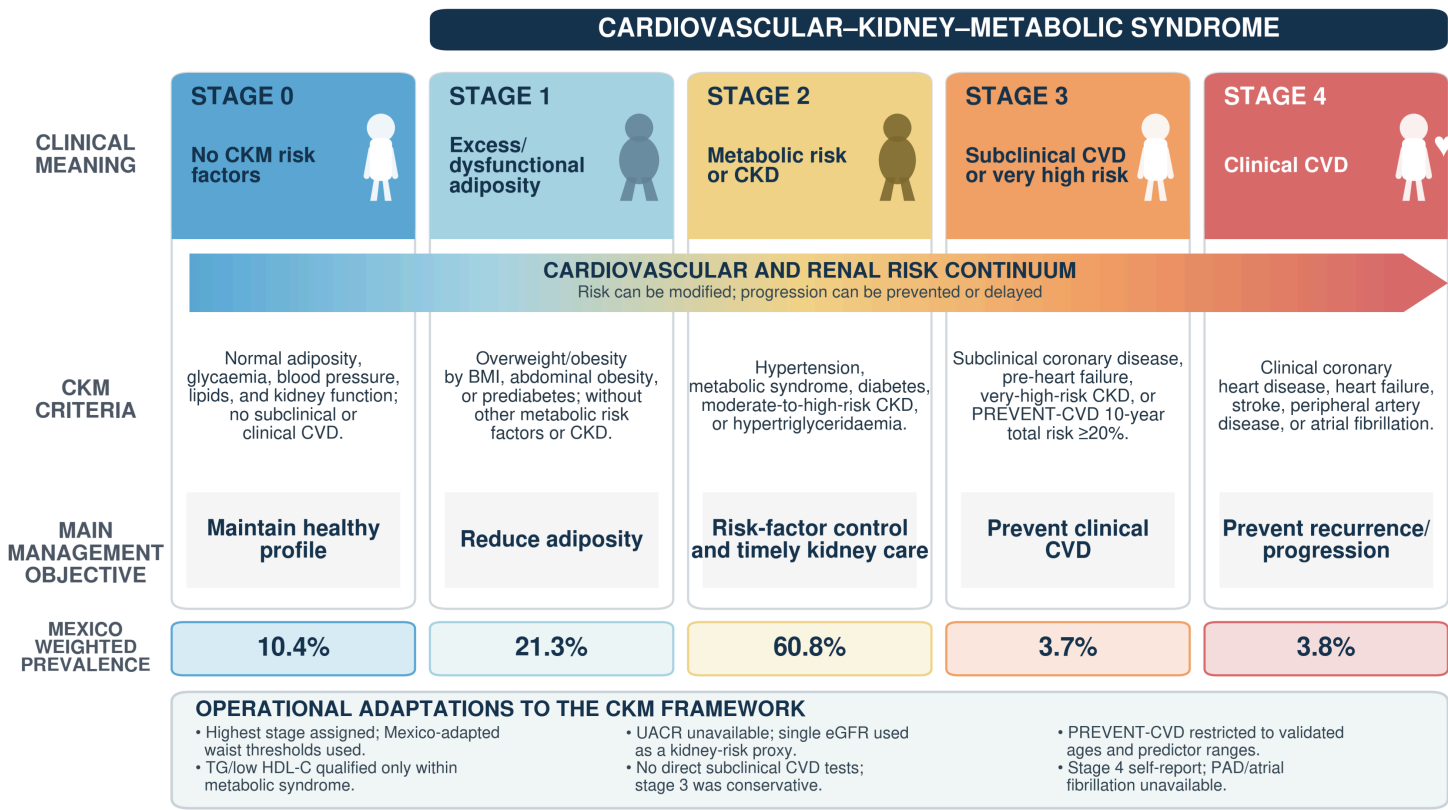


Figure 1

Cardiovascular–kidney–metabolic syndrome stages: clinical implications, study-specific operational adaptations, and prevalence among Mexican adults.

Note: Percentages are weighted national prevalence estimates among nonpregnant Mexican adults aged ≥ 20 years. Participants were assigned hierarchically to their highest qualifying CKM stage. The study-specific operational definitions reflect the variables available in ENSANUT 2018–19. ^a Under the alternative specification allowing fasting triglycerides ≥ 150 mg/dL to independently qualify for stage 2, the prevalences of stage 2 and CKM stages 1–4 were 69.1% and 91.8%, respectively. The complete alternative stage distribution is provided in Supplementary Table S3.

AF=atrial fibrillation; BMI=body mass index; CKM=cardiovascular–kidney–metabolic; CVD=cardiovascular disease; eGFR=estimated glomerular filtration rate; HDL-C=high-density lipoprotein

cholesterol; MI=myocardial infarction; PAD=peripheral artery disease; PREVENT=Predicting Risk of Cardiovascular Disease EVENTS; UACR=urine albumin-to-creatinine ratio.

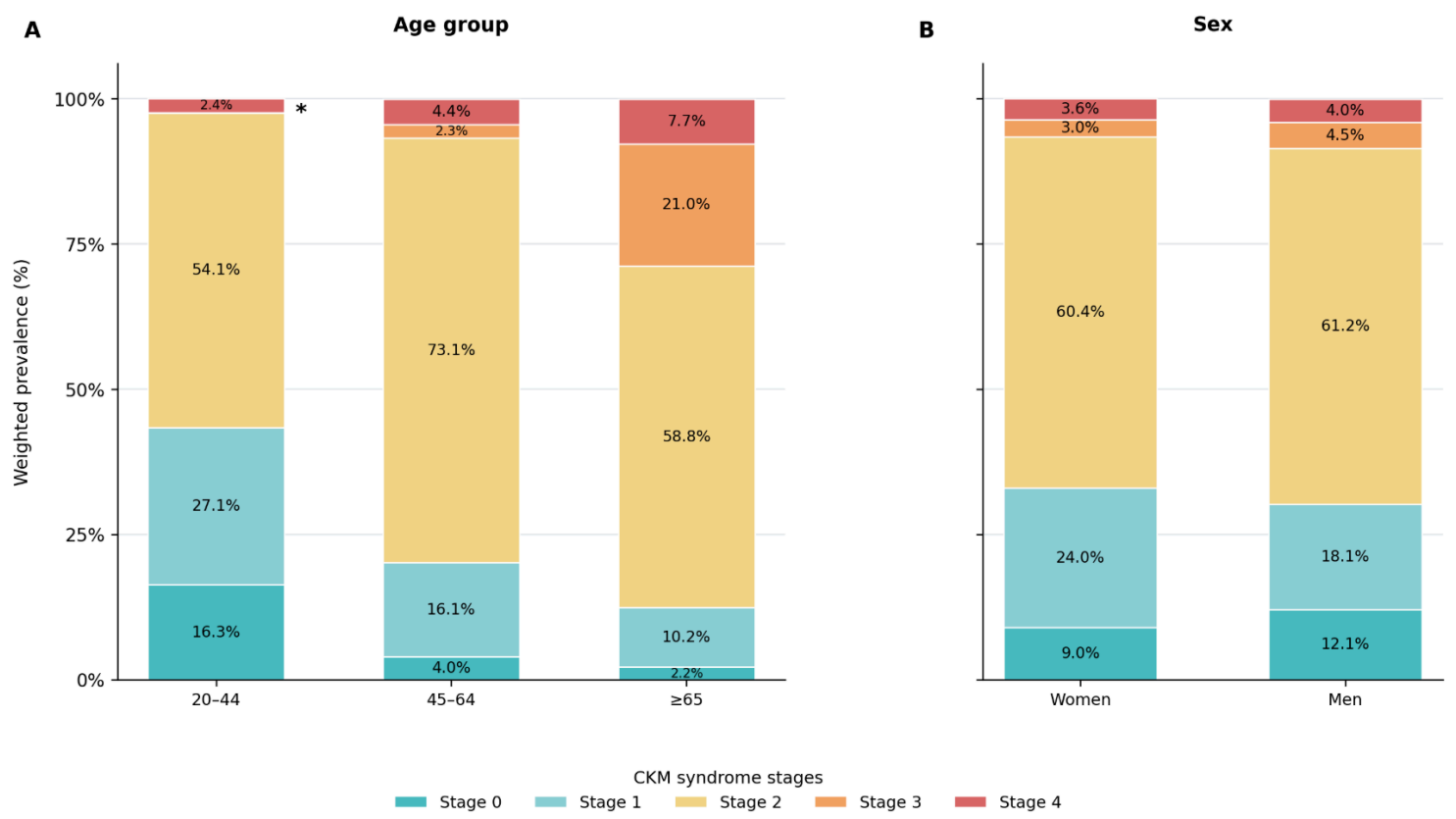


Figure 2

Distribution of CKM stages by age group and sex in Mexican adults.

Note: Bars show weighted national prevalence estimates. The asterisk denotes stage 3 prevalence of 0.1% among adults aged 20–44 years, for which an internal percentage label could not be displayed. Under the alternative specification allowing fasting triglycerides ≥ 150 mg/dL to independently qualify for stage 2, the prevalences of stage 2 and CKM stages 1–4 were 69.1% and 91.8%, respectively. The complete alternative stage distribution is provided in Supplementary Table S3. Percentages may not total 100% because of rounding. CKM=cardiovascular–kidney–metabolic.

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