DOI: 10.1111/j.1464-5491.2009.02795.x

Original Article: Epidemiology

High prevalence of diabetes and impaired fasting glucose in urban Latin America: the CARMELA Study

J. Escobedo, L. V. Buitrón, M. F. Velasco*, J. C. Ramírez, R. Hernández†, A. Macchia‡, F. Pellegrini‡, H. Schargrodsky§, C. Boissonnet¶ and B. M. Champagne** on behalf of the CARMELA Study Investigators[1]

Medical Research Unit on Clinical Epidemiology, Mexican Social Security Institute, Mexico City, Mexico, *Metropolitan Hospital of Quito, Quito, Ecuador, †Clinical Pharmacology Unit and Hypertension Clinic, School of Medicine, Centroccidental University 'Lisandro Alvarado', Medicine Decanato, Barquisimeto, Venezuela, ‡Consorzio Mario Negri Sud, Chieti, Italy, §Department of Cardiology, Italian Hospital of Buenos Aires, Buenos Aires, Argentina, ¶Coronary Care Unit, Medical Education and Clinical Research Center 'Norberto Quirno', Buenos Aires, Argentina and **InterAmerican Heart Foundation, Dallas, TX, USA

Accepted 26 June 2009

Abstract

Aims Cardiovascular risk is increased with glucose metabolism abnormalities. Prevalence data can support public health initiatives required to address this risk. The Cardiovascular Risk Factor Multiple Evaluation in Latin America (CARMELA) study was designed to estimate the prevalence of Type 2 diabetes, impaired fasting glucose and related risk factors in seven urban Latin American populations.

Methods CARMELA was a cross-sectional, population-based study of 11 550 adults 25–64 years of age. With a multi-stage sample design of a probabilistic nature, approximately 1600 subjects were randomly selected in each city.

Results Overall, the prevalence of diabetes was 7.0% (95% confidence intervals 6.5–7.6%). The prevalence of individuals with diabetes or impaired fasting glucose increased with increasing age. In the oldest age category, 55–64 years of age, prevalence of diabetes ranged from 9 to 22% and prevalence of impaired fasting glucose ranged from 3 to 6%. Only 16.3% of people with prior diagnosis of diabetes and who were receiving pharmacologic treatment, were in good glycaemic control (fasting glucose < 6.1 mmol/l). The prevalence of diabetes in individuals with abdominal obesity was approximately twofold higher. Participants with hypertension, elevated serum triglycerides and increased common carotid artery intima-media thickness were also more likely to have diabetes.

Conclusions The prevalence of diabetes and impaired fasting glucose is high in seven major Latin American cities; intervention is needed to avoid substantial medical and socio-economic consequences. CARMELA supports the associations of abdominal obesity, hypertension, elevated serum triglycerides and carotid intima-media thickness with diabetes.

Diabet. Med. 26, 864–871 (2009)

Keywords abdominal obesity, cardiovascular risk factors, carotid intima-media thickness, impaired fasting glucose, Type 2 diabetes mellitus

Abbreviations BMI, body mass index; CARMELA, Cardiovascular Risk Factor Multiple Evaluation in Latin America; CCAIMT, common carotid intima-media thickness; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; OR, odds ratio; WHO, World Health Organization

Introduction

The increasing prevalence of diabetes is a notable public health concern in both developed and developing countries. In the year 2000, diabetes affected approximately 171 million people worldwide, with an additional 197 million having impaired glucose tolerance. By the year 2025, estimates suggest that worldwide prevalence will be 5.4% of the population, with over 75% of the people with diabetes in the world residing in developing countries [1].

Obesity, sedentary lifestyles and dietary changes contribute to the growing rate of diabetes worldwide [2]. Furthermore,

Correspondence to: Jorge Escobedo, MD, FACP, Gabriel Mancera 222, Col. Del Valle, 03100 Mexico City, DF Mexico. E-mail: jorgeep@unam.mx

[1]See Appendix in Supporting information.

diabetes itself is a risk factor for the leading cause of mortality in developing countries, coronary heart disease [3]. In 2002, diabetes was responsible for nearly 1 million deaths [3]. Serious complications associated specifically with diabetes, hypoglycaemia or ketoacidosis, are rarely the cause of death; mortality is more likely to be as a result of cardiovascular or renal complications [4]. Thus, mortality estimates associated with diabetes may actually be low. Another cause for underestimation of the impact of diabetes is the large number of participants with undiagnosed diabetes or pre-diabetes.

Conservative estimates indicate that the presence of diabetes increases the risk of a fatal cardiovascular event by twofold [5]. Impaired fasting glucose is also associated with a modest excess risk of all-cause mortality [6]. The association between glucose control and cardiovascular risk is evident even before there is a definitive diagnosis of diabetes; an increase in cardiovascular risk begins a decade or more before the diagnosis of diabetes is known, making silent or unknown glucose metabolism abnormalities a substantial health threat [7]. Intensively targeting diabetes and other cardiovascular risk factors with behaviour modification and pharmacological therapy (targeting hyperglycaemia, hypertension, dyslipidaemia and microalbuminuria, along with secondary prevention of cardiovascular disease with aspirin), can halve cardiovascular disease risk compared with conventional treatment alone [8].

Knowledge of the prevalence of fasting glucose abnormalities and diabetes is critical to the development of clinical and public health initiatives directed toward minimizing the medical and socio-economic impact of diabetes. The Cardiovascular Risk Factor Multiple Evaluation in Latin America (CARMELA) study was designed to determine and compare cardiovascular risk factor prevalence and common carotid intima-media thickness (CCAIMT) distributions in: Barquisimeto, Venezuela; Bogota, Colombia; Buenos Aires, Argentina; Lima, Peru; Mexico City, Mexico; Quito, Ecuador; and Santiago, Chile [9]. Here, data that were obtained during CARMELA are further analysed to determine the prevalence of diabetes, impaired fasting glucose and associated risk factors.

Patients and methods

This cross-sectional, population-based, observational study, conducted between September 2003 and August 2005, was designed to enroll approximately 1600 participants from each of seven Latin American cities. The study was conducted according to the Declaration of Helsinki and the Guides for Good Clinical Practice. The sampling design distributed the participants into groups stratified by sex and age (into four 10-year age groups). Interviewers, certified and trained by CARMELA investigators, administered an epidemiological questionnaire. Participants made one visit to a designated healthcare institution for all anthropometric and clinical measurements; these measures were standardized across all centres, with health personnel trained, certified and supervised by CARMELA investigators. Additional details of CARMELA methodology have been reported elsewhere [9]. In brief, a multi-stage sample design of a probabilistic nature was employed, providing a pre-determined number of subjects for each age and sex group. The seven cities were first divided into geographical sectors and then into primary sampling units (i.e. city blocks) which were randomly selected for future sampling. Households in these primary sampling units were randomly selected to obtain an equiprobabilistic sample of approximately 200 individuals within each of the four 10-year age groups for males and females.

Blood glucose and lipids

Participants were asked to refrain from using laxatives containing glycerin for 48 h and from consuming glycerin-containing products and other sweets for 24 h prior to blood sampling. Blood was drawn in the fasting state; only water, black coffee or unsweetened tea and medications other than glucose-lowering medications were permitted during the 12 h prior to sampling. Blood was drawn into serum-separating tubes and centrifuged within 2 h. Following blood drawing, participants were allowed to resume their usual glucose-lowering medication. Plasma glucose was assayed within 6 h. Serum was assayed for total cholesterol, high-density lipoprotein cholesterol (HDL-C) and triglycerides; low-density lipoprotein cholesterol (LDL-C) was calculated.

Anthropometric and physical measurements

Participants' height (without footwear) was measured with a vertical measuring scale equipped with a right-angle accessory. Weight was measured with the minimum of clothing. Waist circumference was measured at the midpoint between the last rib and the iliac crest. Blood pressure was measured with the subject seated. Two readings were taken 5 min apart; if they differed by > 5 mmHg, measurements were repeated until two concordant readings were obtained. CCAIMT was measured according to the Mannheim intima-media thickness consensus [10] as described elsewhere.

Definitions of abnormal glucose metabolism

Diabetes was defined as a fasting plasma glucose ≥ 7.0 mmol/l [11] or self-reported diabetes. Impaired fasting glucose was defined as fasting plasma glucose ≥ 6.1 and < 7.0 mmol/l. Fasting plasma glucose < 6.1 mmol/l was considered as good glycaemic control of diabetes.

Statistical analysis

Statistical processing addressed the non-equal probability character of the sample and the structure of the design to generate data adjusted for the age and sex distribution of the population of each city. Prevalence and odds ratios (ORs) along with their 95% confidence intervals were estimated by survey analysis procedures (SAS Software, Release 9.1; SAS Institute,

Cary, NC, USA), taking into account the multistage stratified sampling design via CLUSTER and STRATA statements. Overall prevalence was age-adjusted by the direct method, using the age distribution of the local population. Overall prevalence was also age-adjusted by the age distribution of the 2000 world population, to allow comparison between participant cities. A multivariate logistic regression model was used to assess the strength of the association between the presence of diabetes and studied risk factors. The following risk factors were included in the model: age, sex, triglycerides, HDL-C and LDL-C serum values, hypertension, obesity, abdominal obesity and CCAIMT. All variables were entered in the model using the enter method.

Results

In the CARMELA Study, 11 550 subjects underwent testing for diabetes, impaired fasting glucose and related risk factors. Table 1 shows socio-demographic characteristics of the studied population in the seven cities included. Education and unemployment status resembled those in the general population of the seven cities.

Prevalence

Overall, the prevalence of diabetes was 7.0% [95% confidence intervals (CI) 6.5–7.6]; impaired fasting glucose was found in 2% of the population. The highest prevalence of diabetes was in Mexico City (8.9%; 95% CI 7.7–10.2) and Bogotá (8.1%; 95% CI 6.8–9.5) and the lowest was in Lima (4.4%; 95% CI 3.4–5.4). There was a trend toward higher prevalence of diabetes among women than men in all cities except Buenos Aires (Table 2). Male and female rates followed similar trends, increasing with age. In all cities, the prevalence of diabetes increased with age, ranging from 2% (Barquisimeto and Lima) to 5% in the youngest age groups (25–34 years of age) and from 5.8% (Lima) to 22% (Mexico City) in the two oldest age groups (45–54 and 55–64 years of age) (Table 2). Mexico City and Bogotá also had the highest prevalence of impaired fasting glucose (3%), while Barquisimeto had the lowest (1%). Men tended to have a higher prevalence of impaired fasting glucose than women, with the exception of women from Santiago and Quito, who had a slightly higher prevalence and twice the prevalence, respectively, than their male counterparts. Impaired fasting glucose levels also tended to rise with age; the highest prevalence (6%) was in the oldest age category of individuals from Mexico City.

Previously undiagnosed diabetes occurred in one of every five diabetic patients in the CARMELA Study. Of participants with a history of diabetes mellitus and/or who had received medication for diabetes mellitus, 39% had fasting plasma glucose < 6.1 mmol/l. However, in those who were taking oral glucose-lowering drugs or insulin, only 16.3% had a fasting plasma glucose < 6.1 mmol/l. In Barquisimeto, Bogotá and Santiago, the prevalence of women with diabetes who had desirable fasting plasma glucose was twice as high as the

Table 1 Socio-demographic characteristics of the studied population in the seven cities included in CARMELA

	Barquisimeto	Bogotá	Buenos Aires	Lima	Mexico City	Quito	Santiago
Total (*n*)	1848	1553	1482	1652	1722	1638	1655
Age (mean ± SD)	45.1 ± 11.3	45.1 ± 11.3	44.6 ± 11.7	43.6 ± 11.6	44.5 ± 11.3	44.4 ± 11.2	44.8 ± 11.2
Male sex *n* (%)	713 (38.58)	738 (47.52)	734 (49.53)	769 (46.55)	833 (48.37)	813 (49.63)	783 (47.31)
Illiteracy % (95% CI)	3.6 (2.7–4.5)	1.4 (0.9–1.9)	0.0 (0.0–0.0)	0.5 (0.2–0.8)	0.6 (0.3–0.8)	1.7 (1.1–2.3)	0.6 (0.2–1.0)
Years of education mean (95% CI)	9.0 (8.6–9.3)	9.2 (8.8–9.6)	13.9 (13.5–14.2)	12.9 (12.7–13.2)	12.1 (11.8–12.4)	10.5 (9.9–11.1)	11.7 (11.3–12.0)
Unemployed % (95% CI)	7.0 (5.2–8.7)	13.2 (10.8–15.6)	9.8 (8.1–11.6)	7.6 (6.0–9.3)	2.5 (1.3–3.8)	5.5 (3.8–7.3)	9.4 (7.7–11.2)
Living alone % (95% CI)	1.4 (0.9–1.9)	2.2 (1.4–3.0)	9.9 (7.8–12.1)	1.1 (0.5–1.7)	3.1 (2.2–4.0)	2.2 (1.3–3.1)	1.9 (1.2–2.7)

CARMELA, Cardiovascular Risk Factor Multiple Evaluation in Latin America; CI, confidence interval; SD, standard deviation.

Table 2 Prevalence of diabetes mellitus* (%) (95% confidence interval) by risk factors and markers

	Barquisimeto	Bogotá	Buenos Aires	Lima	Mexico City	Quito	Santiago
Overall prevalence							
Weighted†	6.0 (5.0–7.0)	8.1 (6.8–9.5)	6.2 (4.8–7.7)	4.4 (3.4–5.4)	8.9 (7.7–10.2)	5.9 (4.8–7.1)	7.2 (5.9–8.6)
Age-adjusted‡	6.4 (5.4–7.6)	8.5 (7.1–9.9)	5.8 (4.7–7.0)	4.5 (3.5–5.5)	9.5 (8.2–10.9)	6.2 (5.1–7.4)	7.1 (6.0–8.4)
Age group (years)							
25–34	2.2 (0.7–3.8)	4.7 (2.5–6.8)	2.4 (0.8–4.0)	2.2 (0.9–3.5)	3.4 (1.8–4.9)	2.9 (1.1–4.6)	2.3 (0.7–3.9)
35–44	5.7 (3.6–7.9)	5.5 (3.2–7.9)	5.9 (2.8–9.0)	4.2 (2.1–6.4)	6.1 (3.9–8.3)	5.9 (3.5–8.3)	4.9 (2.8–7.0)
45–54	7.2 (5.1–9.3)	12.4 (9.4–15.3)	6.3 (3.4–9.1)	5.8 (3.6–7.9)	15.5 (12.2–18.8)	9.4 (6.4–12.3)	11.8 (8.7–14.9)
55–64	16.9 (13.6–20.3)	17.7 (13.7–21.6)	12.5 (9.0–16.0)	8.7 (5.8–11.6)	22.1 (18.5–25.7)	10.0 (7.5–12.6)	16.3 (12.7–20.0)
Sex							
Male	5.6 (4.0–7.2)	7.4 (5.7–9.2)	7.9 (5.7–10.0)	4.3 (2.8–5.7)	8.0 (6.3–9.7)	4.6 (3.2–6.0)	6.8 (5.2–8.5)
Female	6.3 (5.0–7.5)	8.7 (6.8–10.6)	4.8 (3.3–6.4)	4.6 (3.2–5.9)	9.7 (7.8–11.6)	7.3 (5.6–8.9)	7.6 (5.6–9.6)
CCAIMT (tertiles)§							
I	3.2 (1.9–4.6)	4.1 (2.2–5.9)	3.3 (1.6–5.1)	2.2 (0.9–3.5)	6.6 (4.2–8.9)	4.5 (2.7–6.3)	3.1 (1.7–4.6)
II	5.2 (3.5–7.0)	9.9 (6.2–13.6)	4.1 (1.9–6.4)	3.0 (1.5–4.4)	7.6 (5.2–10.1)	6.5 (3.9–9.0)	7.7 (5.4–10.0)
III	11.6 (9.0–14.1)	15.8 (12.5–19.2)	11.2 (8.0–14.3)	9.0 (6.5–11.6)	13.6 (10.7–16.5)	8.9 (6.1–11.7)	12.2 (9.4–15.0)
Abdominal obesity¶							
Absent	4.6 (3.5–5.7)	6.9 (5.5–8.4)	3.2 (2.1–4.2)	3.3 (2.3–4.2)	6.0 (4.6–7.4)	4.6 (3.3–5.8)	4.8 (3.6–6.0)
Present	9.6 (7.3–11.9)	12.1 (9.0–15.3)	13.6 (9.9–17.3)	8.6 (5.9–11.2)	12.6 (10.3–14.9)	10.5 (7.7–13.2)	12.6 (9.7–15.6)
Obesity (BMI kg/m^2)**							
< 25.0	4.0 (2.6–5.3)	6.2 (4.4–8.1)	2.4 (1.3–3.6)	2.6 (1.4–3.9)	4.6 (3.1–6.1)	3.5 (1.9–5.2)	4.8 (3.0–6.5)
25.0–29.9	6.1 (4.3–7.9)	7.8 (5.6–10.0)	5.7 (3.9–7.4)	4.1 (2.8–5.4)	8.9 (7.0–10.8)	7.2 (5.3–9.1)	5.3 (3.7–7.0)
≥ 30.0	9.3 (6.9–11.8)	13.5 (9.4–17.6)	15.9 (10.8–20.9)	8.0 (5.4–10.7)	12.8 (9.8–15.8)	8.4 (5.5–11.4)	13.3 (9.9–16.7)
Hypertension††							
Absent	3.8 (2.9–4.8)	6.6 (5.2–8.0)	3.9 (2.6–5.3)	3.4 (2.4–4.3)	7.3 (6.0–8.5)	5.3 (4.1–6.5)	4.7 (3.6–5.8)
Present	12.6 (9.9–15.4)	18.3 (13.6–22.9)	11.9 (8.5–15.2)	11.6 (7.5–15.8)	21.7 (16.7–26.6)	12.9 (8.6–17.2)	15.3 (11.7–18.8)
LDL-C (mmol/l)							
< 2.6	4.2 (2.9–5.5)	6.8 (4.7–8.9)	4.6 (2.5–6.7)	3.1 (1.6–4.7)	8.5 (6.4–10.6)	4.8 (2.4–7.1)	7.0 (4.6–9.3)
2.6–3.3	5.6 (3.8–7.4)	6.6 (4.2–8.9)	5.2 (3.1–7.3)	2.9 (1.6–4.2)	7.9 (5.5–10.3)	4.4 (2.5–6.3)	7.5 (5.4–9.6)
3.4–4.1	7.0 (3.9–10.2)	7.4 (4.5–10.4)	6.3 (3.6–8.9)	6.1 (3.9–8.3)	7.7 (5.3–10.1)	8.1 (5.5–10.6)	6.4 (4.3–8.6)
≥ 4.2	11.9 (6.4–17.3)	11.6 (7.1–16.0)	7.8 (4.5–11.2)	6.8 (2.9–10.6)	10.3 (6.2–14.3)	6.3 (3.7–8.9)	6.0 (2.7–9.3)
Low HDL-C‡‡							
No	4.4 (2.8–6.0)	7.8 (5.4–10.2)	4.8 (3.4–6.2)	2.3 (1.1–3.5)	6.3 (5.0–7.6)	4.3 (3.0–5.5)	5.8 (4.3–7.3)
Yes	6.6 (5.4–7.8)	8.3 (6.6–10.0)	9.5 (6.7–12.3)	5.2 (4.0–6.5)	13.1 (10.6–15.7)	8.7 (6.6–10.9)	9.5 (7.0–12.1)
Triglycerides (mmol/l)							
< 1.7	3.9 (2.8–5.0)	6.2 (4.6–7.9)	4.6 (3.2–5.9)	3.0 (2.0–4.0)	5.2 (4.0–6.5)	4.0 (2.8–5.1)	4.5 (3.2–5.9)
1.7–2.2	7.5 (4.8–10.2)	6.3 (3.9–8.8)	6.5 (2.7–10.3)	4.2 (1.9–6.6)	8.8 (5.8–11.7)	7.7 (4.6–10.8)	8.6 (5.5–11.6)
≥ 2.3	11.3 (8.5–14.0)	14.4 (11.1–17.7)	19.4 (12.4–26.4)	9.4 (6.2–12.6)	14.6 (12.5–16.6)	9.4 (6.8–12.0)	13.4 (9.9–17.0)

*Diabetes mellitus by history or fasting plasma glucose ≥ 7.0 mmol/l.
†Weighted prevalence: age-adjusted by the age distribution of local population.
‡Age-adjusted prevalence by the age distribution of the 2000 world population.
§CCAIMT values were divided in tertiles of the whole population.
¶Abdominal obesity: waist circumference > 102 cm in men and > 88 cm in women.
**Obesity: body mass index ≥ 30 kg/m^2.
††Hypertension: ≥ 140/90 mmHg or current antihypertensive medication use [24].
‡‡HDL-C: low ≤ 1.03 mmol/l in men or ≤ 1.29 mmol/l in women.
BMI, body mass index; CCAIMT, common carotid artery intima-media thickness; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

prevalence of their male counterparts; in other cities, male and female rates were similar.

Prevalence of diabetes in participants with other cardiovascular risk factors

Participants in CARMELA with other cardiovascular risk factors were more likely to have diabetes than their counterparts without these risk factors (Tables 2 and 3). The prevalence of diabetes increased with increasing CCAIMT. Abdominal adiposity, but not body mass index (BMI), was associated with an increased prevalence of diabetes.

Discussion

According to the World Health Organization (WHO), the worldwide prevalence of diabetes was 4% in 1995 and is predicted to rise to 5.4% by 2025 [1]. Alarmingly, CARMELA found a weighted prevalence of diabetes of 7% and an age-adjusted prevalence of 6.9% (using the 2000 world population as

Table 3 Adjusted odds ratios for diabetes mellitus (95% confidence interval) derived from the multivariate logistic regression model*

	Barquisimeto	Bogota	Buenos Aires	Lima
(a)				
Age group (years)				
25–34	1.0	1.0	1.0	1.0
35–44	1.83 (0.75–4.45)	0.84 (0.40–1.77)	1.70 (0.66–4.36)	1.63 (0.58–4.60)
45–54	1.48 (0.62–3.58)	1.27 (0.59–2.70)	1.45 (0.41–5.14)	1.47 (0.53–4.12)
55–64	3.46 (1.40–8.57)	1.61 (0.74–3.52)	2.82 (0.88–9.07)	1.60 (0.57–4.48)
Sex				
Male	1.0	1.0	1.0	1.0
Female	1.07 (0.65–1.77)	1.93 (1.21–3.07)	0.83 (0.46–1.50)	1.41 (0.78–2.55)
CCAIMT (tertiles)†				
I	1.0	1.0	1.0	1.0
II	0.88 (0.47–1.62)	2.16 (1.00–4.64)	0.94 (0.38–2.33)	1.27 (0.45–3.57)
III	1.31 (0.69–2.50)	2.54 (0.99–6.52)	1.43 (0.58–3.48)	3.18 (1.17–8.68)
Abdominal obesity‡				
Yes	1.19 (0.72–1.97)	0.66 (0.36–1.19)	1.57 (0.76–3.24)	1.80 (0.93–3.47)
Obesity (BMI kg/m^2)§				
< 25.0	1.0	1.0	1.0	1.0
25.0–29.9	1.16 (0.66–2.05)	1.01 (0.57–1.79)	1.27 (0.61–2.65)	0.80 (0.41–1.56)
≥ 30.0	1.25 (0.65–2.41)	1.52 (0.75–3.08)	2.34 (0.86–6.36)	0.73 (0.32–1.68)
Hypertension¶				
Yes	2.22 (1.39–3.53)	2.12 (1.19–3.76)	1.48 (0.86–2.57)	1.88 (1.04–3.40)
LDL-C (mmol/l)				
< 2.6	1.0	1.0	1.0	1.0
2.6–3.3	1.13 (0.69–1.86)	0.79 (0.45–1.42)	0.87 (0.37–2.04)	0.70 (0.32–1.55)
3.4–4.1	1.18 (0.62–2.24)	1.07 (0.60–1.92)	0.84 (0.35–2.04)	1.26 (0.60–2.65)
≥ 4.2	1.81 (0.96–3.43)	1.57 (0.79–3.13)	0.79 (0.33–1.92)	1.12 (0.40–3.14)
Low HDL-C**				
Yes	1.2 (0.72–1.98)	0.63 (0.37–1.07)	1.14 (0.71–1.82)	1.75 (0.97–3.17)
Triglycerides (mmol/l)				
< 1.7	1.0	1.0	1.0	1.0
1.7–2.3	1.37 (0.80–2.35)	0.8 (0.42–1.52)	1.04 (0.48–2.26)	0.99 (0.48–2.00)
≥ 2.4	1.60 (0.94–2.71)	2.12 (1.27–3.55)	2.18 (0.99–4.76)	1.93 (1.03–3.60)
	Mexico City	**Quito**	**Santiago**	**Overall**
(b)				
Age group (years)				
25–34	1.0	1.0	1.0	1.0
35–44	1.69 (0.87–3.29)	3.02 (1.12–8.13)	1.64 (0.63–4.27)	1.46 (1.02–2.08)
45–54	5.45 (2.84–10.45)	3.49 (1.38–8.80)	4.16 (1.60–10.85)	2.72 (1.88–3.94)
55–64	6.83 (3.68–12.69)	3.73 (1.38–10.06)	5.61 (2.00–15.73)	3.47 (2.41–5.00)
Sex				
Male	1.0	1.0	1.0	1.0
Female	1.14 (0.77–1.70)	1.22 (0.66–2.26)	1.00 (0.65–1.56)	1.25 (1.02–1.53)
CCAIMT (tertiles)†				
I	1.0	1.0	1.0	1.0
II	1.05 (0.55–2.02)	0.75 (0.37–1.54)	1.28 (0.68–2.39)	1.20 (0.86–1.67)
III	1.52 (0.84–2.75)	0.76 (0.37–1.58)	1.17 (0.60–2.30)	1.52 (1.08–2.13)
Abdominal obesity‡				
Yes	1.38 (0.95–1.99)	1.76 (0.84–3.67)	1.69 (0.96–2.95)	1.44 (1.15–1.81)
Obesity (BMI kg/m^2)§				
< 25.0	1.0	1.0	1.0	1.0
25.0–29.9	1.02 (0.63–1.66)	1.60 (0.83–3.07)	0.93 (0.50–1.72)	1.01 (0.78–1.31)
≥ 30.0	1.32 (0.78–2.23)	1.06 (0.44–2.53)	1.37 (0.61–3.09)	1.24 (0.92–1.68)
Hypertension¶				
Yes	1.48 (1.01–2.16)	1.94 (1.08–3.47)	1.66 (1.13–2.42)	1.68 (1.37–2.06)

Table 3 *Continued*

	Mexico City	Quito	Santiago	Overall
LDL-C (mmol/l)				
< 2.6	1.0	1.0	1.0	1.0
2.6–3.3	0.76 (0.46–1.26)	1.07 (0.50–2.28)	0.84 (0.54–1.32)	0.79 (0.62–1.00)
3.4–4.1	0.66 (0.41–1.07)	1.33 (0.64–2.79)	0.54 (0.30–0.95)	0.80 (0.62–1.03)
≥ 4.2	0.73 (0.41–1.30)	1.17 (0.55–2.45)	0.40 (0.18–0.89)	0.80 (0.58–1.09)
Low HDL-C**				
Yes	1.84 (1.22–2.76)	1.41 (0.81–2.46)	1.16 (0.71–1.91)	1.12 (0.91–1.38)
Triglycerides (mmol/l)				
< 1.7	1.0	1.0	1.0	1.0
1.7–2.3	1.23 (0.83–1.82)	1.42 (0.74–2.71)	1.46 (0.89–2.38)	1.21 (0.96–1.52)
≥ 2.4	1.95 (1.27–2.99)	1.91 (1.17–3.13)	2.14 (1.20–3.79)	2.15 (1.72–2.70)

*Variables included in the adjustment: age, sex, CCAIMT, waist circumference, BMI, hypertension and serum LDL-C, HDL-C and triglycerides.
†CCAIMT values were divided in tertiles assessed within each city, taking the first tertile as the reference category.
‡Abdominal obesity: waist circumference > 102 cm in men and > 88 cm in women.
§Obesity: body mass index ≥ 30 kg/m^2.
¶Hypertension: ≥ 140/90 mmHg or current antihypertensive medication use [24].
**HDL-C: low ≤ 1.03 mmol/l in men or ≤ 1.29 mmol/l in women.
BMI, body mass index; CCAIMT, common carotid artery intima-media thickness; HDL-C, high density lipoprotein cholesterol; LDL-C, low density lipoprotein cholesterol.

reference), not only surpassing regional estimates of 6% only a few years ago [1], but also clearly surpassing worldwide expectations for 2025, even although the youngest participants in CARMELA were older (25 years old instead of 20 as WHO), whilst subjects aged ≥ 65 years were excluded. Moreover, CARMELA findings may actually under-report the Latin American prevalence when compared with the above-mentioned WHO criteria estimates because they were based on fasting plasma glucose ≥ 7.0 mmol/l for the diagnosis of diabetes mellitus, which gives lower prevalence estimates than the oral glucose tolerance test used in the WHO criteria [11,12]. Another drawback from not having used the oral glucose tolerance test is the inability to assess impaired glucose tolerance. Nevertheless, coupled with the prediction that developing countries will see an increase in diabetes that is 128% more than developed regions [1], urban Latin America faces a diabetes epidemic that will have extensive medical and socio-economic consequences. On the one hand, if the cut-off value for impaired fasting glucose was lowered to 5.6 mmol/l, as proposed by the American Diabetes Association [12], the prevalence of IFG would be 12.5% and the burden of glucose abnormalities would be even higher. On the other hand, CARMELA may have overestimated the prevalence of diabetes, as self-reporting may reflect misdiagnosis. The mean fasting plasma glucose of those with a previous diagnosis of diabetes was 8.1 mmol/l. However, in those receiving oral glucose lowering drugs or insulin, the mean value was 10.4 mmol/l and only 16.3% were well controlled, with a fasting plasma glucose < 6.1 mmol/l.

The demographics of diabetes differ in developing and developed countries [1,13]: developing countries have the greatest burden of disease concentrated in the 45- to 64- year-old age group, whereas, in developed countries, the greatest burden of disease is in those individuals aged > 65 years [1]. Despite variable rates of diabetes across CARMELA cities, the prevalence of both impaired fasting glucose levels and diabetes increased with age in both sexes; the prevalence of diabetes in the two oldest age groups ranged from 6% (Lima) to as high as 22% (Mexico City). It is more common for women in developed countries to have a higher prevalence of diabetes than men, while there is an equal sex distribution of diabetes in developing countries [1]. In each CARMELA city, unlike other developing regions, there was a higher prevalence of female diabetic patients than male, except in Buenos Aires. Using pharmacological and/or non-pharmacological methods, only 16.4% of individuals with diabetes mellitus were well controlled at the currently accepted fasting plasma glucose level (< 6.1 mmol/l).

Participants with modifiable cardiovascular risk factors (e.g. hypertension, lipid abnormalities, tobacco use, obesity, metabolic syndrome, diabetes mellitus) are at increased risk of poor cardiovascular outcomes [8]. Recognizing that diabetes frequently occurs with other cardiovascular risk factors, public health policies must be designed to address the rising epidemic of diabetes mellitus and target appropriate populations for aggressive risk management.

CARMELA identified hypertension as one of the most common cardiovascular risk factors associated with Type 2 diabetes—hypertensive participants were 1.5–2.2 times more likely to have diabetes than normotensive participants. Other studies have also documented this relationship, finding that 34–67% of individuals newly diagnosed with Type 2 diabetes in Argentina and Colombia also had hypertension [14].

The co-morbidity of diabetes and dyslipidaemia is also relatively common. Dyslipidaemia was found in 53–69% of newly diagnosed diabetic patients in a study from Argentina and

Colombia [14]. A study conducted in Mexico more than a decade ago, showed that both serum cholesterol and diabetes were significant contributors to cardiovascular mortality [15]. As elsewhere in the literature [16], evidence of a strong association was noted between elevated triglycerides and the presence of diabetes in CARMELA participants. Associations between low HDL-C and increased diabetes prevalence were also observed in CARMELA, while increasing LDL-C levels generally did not correspond with increased prevalence of diabetes.

The increasing prevalence of diabetes has been linked to the obesity epidemic, with excess weight accounting for about 90% of Type 2 diabetes [2]. In other studies, increases in BMI have been associated with an increased likelihood of having diabetes and diabetes-related cardiovascular co-morbidity [17], particularly in individuals ≥ 60 years of age [18]. However, body fat distribution, in particular abdominal obesity, may be a better predictor of diabetes than BMI [19]. Accordingly, the Mexican National Health Survey 2000 showed that abdominal obesity correlated better with co-morbidities (e.g. diabetes, hypertension) than BMI [20]. Likewise, in CARMELA, abdominal obesity was a strong predictor of diabetes in participants 25–64 years of age, more so than BMI.

Elevated CCAIMT has also been strongly associated with Type 2 diabetes [21]. In the present study, individuals in the highest tertile of CCAIMT had a higher prevalence of diabetes than individuals in the first or second CCAIMT tertiles. While the absolute percentage was different for the seven cities (range 9–16%), the progression of increasing prevalence of diabetes in each tertile of CCAIMT was similar.

As CARMELA is a cross-sectional study, there are some limitations on the observed associations that characterize this study design, lack of follow-up being the main one. Nevertheless, cross-sectional studies are particularly useful for describing characteristics of a target population.

The economic burden as a result of diabetes, its associated co-morbidities and complications is growing at a staggering pace. CARMELA participants were all younger than 65 years, encompassing individuals in their productive years. The economic consequences of diabetes in relatively young individuals remain undefined; however, diabetes would be expected to impact on both the labour supply and productivity levels [22]. Over only a 2-year period (from 2003 to 2005) in Mexico, direct and indirect costs of managing diabetes were projected to increase 26% in the three main public institutions [23]. Moreover, when the high prevalence of fasting glucose abnormalities that were identified in this study and the age of the population affected are factored in, the socio-economic impact of diabetes in Latin America may exceed earlier predictions.

The high prevalence of diabetes and impaired fasting glucose in these seven Latin American cities presents substantial public health concerns and suggests that immediate intervention is needed to avoid significant medical and socio-economic consequences. Early clinical and population-based intervention can prevent or modify progression of diabetes, delay the appearance of macro- and microvascular complications and reduce cardiovascular morbidity and mortality—crucial public health goals. Data from CARMELA support the associations of abdominal obesity, hypertension, elevated serum triglycerides and CCAIMT with diabetes in Latin America and indicate that multi-faceted public health efforts are essential.

Competing interests

Nothing to declare.

Acknowledgements

The authors would like to thank participating institutions, coordinators and investigators: Asociación Cardiovascular Centro Occidental; Pontificia Universidad Javeriana de Bogotá; Centro de Educación Médica e Investigaciones Clínicas 'Norberto Quirno'; Universidad Cayetano Heredia; Instituto Mexicano del Seguro Social; Hospital Metropolitano de Quito; Pontificia Universidad Católica de Santiago de Chile; Marta Torres for compiling clinical laboratory analysis; Héctor Rosso for database design and administration; Javier Valenzuela for administrative and communication assistance. Editorial support was provided by Beth Young, PhD and Lynn Rudich, MD at Envision Pharma and was funded by Pfizer Inc. The CARMELA Study was funded by Pfizer Inc.

References

1 King H, Aubert R, Herman W. Global burden of diabetes, 1995–2025. Prevalence, numerical estimates, and projections. *Diabetes Care* 1998; **21**: 1414–1431.
2 Hossain P, Kawar B, El Nahas M. Obesity and diabetes in the developing world—a growing challenge. *N Engl J Med* 2007; **356**: 213–215.
3 Yach D, Hawkes C, Gould C, Hofman K. The global burden of chronic diseases: overcoming impediments to prevention and control. *J Am Med Assoc* 2004; **291**: 2616–2622.
4 Roglic G, Unwin N, Bennett PH, Mathers C, Tuomilehto J, Nag S *et al.* The burden of mortality attributable to diabetes. Realistic estimates for the year 2000. *Diabetes Care* 2005; **28**: 2130–2135.
5 Huxley R, Barzi F, Woodward M. Excess risk of fatal coronary heart disease associated with diabetes in men and women: meta-analysis of 37 prospective cohort studies. *Br Med J* 2006; **332**: 73–78.
6 Wild S, Smith F, Lee A, Fowkes F. Criteria for previously undiagnosed diabetes and risk of mortality: 15 year follow-up of the Edinburgh Artery Study cohort. *Diabet Med* 2005; **22**: 490–496.
7 Schnell O. The links between diabetes and cardiovascular disease. *J Interv Cardiol* 2005; **18**: 413–416.
8 Gaede P, Vedel P, Larsen M, Jensen G, Parving H-H, Pedersen O. Multifactorial intervention and cardiovascular disease in patients with type 2 diabetes. *N Engl J Med* 2003; **348**: 383–393.
9 Schargrodsky H, Hernandez-Hernandez R, Champagne BM, Silva H, Vinueza R, Silva Ayçaguer LC *et al.* CARMELA Study Investigators. CARMELA: assessment of cardiovascular risk in seven Latin American cities. *Am J Med* 2008; **121**: 58–65.
10 Touboul PJ, Hennerici MG, Meairs S, Adams H, Amarenco P, Bornstein N *et al.* Advisory Board of the 3rd Watching the Risk Symposium 2004, 13th European Stroke Conference: Mannheim intima-media thickness consensus. *Cerebrovasc Dis* 2004; **18**: 346–349.

11 WHO. *Definition and Diagnosis of Diabetes Mellitus and Intermediate Hyperglycemia: Report of a WHO/IDF Consultation*. Geneva: World Health Organization, 2006.
12 American Diabetes Association. Diagnosis and classification of diabetes mellitus. *Diabetes Care* 2009; **32**: S62–S67.
13 Basu R, Dalla Man C, Campioni M, Basu A, Klee G, Toffolo G *et al*. Effects of age and sex on postprandial glucose metabolism. Differences in glucose turnover, insulin secretion, insulin action, and hepatic insulin extraction. *Diabetes* 2006; **55**: 2001–2014.
14 Aschner P. Diabetes trends in Latin America. *Diabetes Metab Res Rev* 2002; **18**: S27–S31.
15 Escobedo de la Peña J, Escamilla Cejudo J, Santos-Burgoa C. Serum cholesterol and diabetes mellitus: main independent risk factors of coronary heart disease mortality in Mexicans. *Arch Inst Cardiol Mex* 1994; **64**: 189–195.
16 Bonora E, Kiechl S, Willeit J, Oberhollenzer F, Egger G, Meigs JB *et al*. Bruneck study: population-based incidence rates and risk factors for type 2 diabetes in white individuals. The Bruneck Study. *Diabetes* 2004; **53**: 1782–1789.
17 Sullivan P, Morrato E, Ghushchyan V, Wyatt H, Hill J. Obesity, inactivity, and the prevalence of diabetes and diabetes-related cardiovascular comorbidities in the US, 2000–2022. *Diabetes Care* 2005; **28**: 1599–1603.
18 Barcelo A, Pelaez M, Rodriguez-Wong L, Pastor-Valero M. The prevalence of diagnosed diabetes among the elderly of seven cities in Latin America and the Caribbean. *J Aging Health* 2006; **18**: 224–239.
19 Meisinger C, Doring A, Thorand B, Heier M, Lowel H. Body fat distribution and risk of type 2 diabetes in the general population: are there differences between men and women? The MONIKA/KORA Augsburg cohort study. *Am J Clin Nutr* 2006; **84**: 483–489.
20 Sanchez-Castillo C, Velazquez-Monroy O, Lara-Esqueda A, Berber A, Sepulveda J, Tapia-Conyer R *et al*. Diabetes and hypertension increases in a society with abdominal obesity: results of the Mexican National Health Survey 2000. *Public Health Nutr* 2005; **8**: 53–60.
21 Hunt K, Williams K, Rivera D, O'Leary DH, Haffner SM, Stern MP *et al*. Elevated carotid artery intima-media thickness levels in individuals who subsequently develop type 2 diabetes. *Arterioscler Thromb Vasc Biol* 2003; **23**: 1845–1850.
22 Suhrcke M, Nugent R, Stuckler D, Rocco L. *Chronic Disease: an Economic Perspective*. London: Oxford Health Alliance, 2006.
23 Arredondo A, Zuñiga A. Economic consequences of epidemiological changes in diabetes in middle-income countries: the Mexican case. *Diabetes Care* 2004; **27**: 104–109.
24 Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, Izzo JL *et al*. National Heart, Lung, and Blood Institute Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure; National High Blood Pressure Education Program Coordinating Committee: The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure: the JNC 7 report. *J Am Med Assoc* 2003; **289**: 2560–2572.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Appendix. CARMELA Study committee members and investigators.

Please note: Wiley-Blackwell are not responsible for the content or functionality of any supporting materials supplied by the authors. Any queries (other than for missing material) should be directed to the corresponding author for the article.

