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On the problem of type 2 diabetes-related mortality in the Canary Islands, Spain. The DARIOS Study

Itahisa Marcelino-Rodríguez [a,b], *Roberto Elosua* [b,c,d], *María del Cristo Rodríguez Pérez* [a,b], *Daniel Fernández-Bergés* [e], *María Jesús Guembe* [f], *Tomás Vega Alonso* [g], *Francisco Javier Félix* [h], *Delia Almeida González* [a,b], *Honorato Ortiz-Marrón* [i], *Fernando Rigo* [j], *José Lapetra* [k,l], *Diana Gavrila* [m,d], *Antonio Segura* [b,n], *Montserrat Fitó* [o], *Judith Peñafiel* [b,c], *Jaume Marrugat* [b,c], *Antonio Cabrera de León* [b,c,p,*]

[a] *Unidad de Investigación de Atención Primaria y del Hospital Universitario Nuestra Señora de Candelaria, Santa Cruz de Tenerife, España*

[b] *Red de Investigación Cardiovascular del Instituto Carlos III Institute de Salud, Madrid, España*

[c] *Grupo de Epidemiología y Genética Cardiovascular, Programa de Investigación en Procesos Inflamatorios y Cardiovasculares, IMIM, Barcelona, España*

[d] *CIBER Epidemiología y Salud Pública (CIBERESP), Madrid, España*

[e] *Unidad de Investigación Don Benito Villanueva, Programa de Investigación Cardiovascular, Fundesalud, Gerencia Área Sanitaria Don Benito-Villanueva, Badajoz, España*

[f] *Servicio de Docencia y Desarrollo Sanitarios, Grupo de Investigación Riesgo Vascular en Navarra (RIVANA), Departamento de Salud, Gobierno de Navarra, Pamplona, España*

[g] *Dirección General de Salud Pública e Investigación Desarrollo e Innovación, Consejería de Sanidad de la Junta de Castilla y León, Valladolid, España*

[h] *Centro de Salud Villanueva Norte, Servicio Extremeño de Salud, Villanueva de la Serena, Badajoz, España*

[i] *Servicio de Epidemiología. Subdirección General de Promoción de la Salud y Prevención, Servicio Madrileño de Salud, Madrid, España*

[j] *Grupo Cardiovascular de Baleares de redIAPP, UB Genova, Palma de Mallorca, España*

[k] *Centro de Salud Universitario "San Pablo", Distrito Sanitario Atención Primaria Sevilla, Servicio Andaluz de Salud, Sevilla, España*

[l] *CIBER de Fisiopatología de la Obesidad y Nutrición, Instituto de Salud Carlos III, Madrid, España*

[m] *Servicio de Epidemiología, Consejería de Sanidad y Consumo de la Región de Murcia, Murcia, España*

[n] *Servicio de Investigación, Instituto de Ciencias de la Salud de Castilla-La Mancha, Toledo, Talavera de la Reina, España*

[o] *Grupo de Riesgo Cardiovascular y Nutrición, Programa de Investigación en Procesos Inflamatorios y Cardiovasculares, IMIM, Barcelona, España*

[p] *Área de Medicina Preventiva y Salud Pública, Universidad de La Laguna, La Laguna, España*

* Corresponding author at: Hospital Universitario de la Candelaria, Unidad de Investigación, Carretera de El Rosario 145, 38010 Santa Cruz de Tenerife, Spain. Tel.: +34 922 600 566; fax: +34 922 600 562.

E-mail address: acableo@gobiernodecanarias.org (A.C.d. León).

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ABSTRACT

Aims: To compare diabetes-related mortality rates and factors associated with this disease in the Canary Islands compared with other 10 Spanish regions.

Methods: In a cross-sectional study of 28,887 participants aged 35–74 years in Spain, data were obtained for diabetes, hypertension, dyslipidemia, obesity, insulin resistance (IR), and metabolic syndrome. Healthcare was measured as awareness, treatment and control of diabetes, dyslipidemia, and hypertension. Standardized mortality rate ratios (SRR) were calculated for the years 1981 to 2011 in the same regions.

Results: Diabetes, obesity, and hypertension were more prevalent in people under the age of 64 in the Canary Islands than in Spain. For all ages, metabolic syndrome and insulin resistance (IR) were also more prevalent in those from the Canary Islands. Healthcare parameters were similar in those from the Canary Islands and the rest of Spain. Diabetes-related mortality in the Canary Islands was the highest in Spain since 1981; the maximum SRR was reached in 2011 in men (6.3 versus the region of Madrid; $p < 0.001$) and women (9.5 versus Madrid; $p < 0.001$). Excess mortality was prevalent from the age of 45 years and above.

Conclusions: Diabetes-related mortality is higher in the Canary Islands population than in any other Spanish region. The high mortality and prevalence of IR warrants investigation of the genetic background associated with a higher incidence and poor prognosis for diabetes in this population. The rise in SRR calls for a rapid public health policy response.

1. Introduction

The seven Canary Islands are one of the 17 regions of Spain and have a population of more than 2.1 million. The prevalence of type 2 diabetes mellitus in this population has been high in recent decades but data suggest that it is similar to other parts of Spain and countries where the disease has also reached epidemic proportions [1–3]. Similarities in prevalence among different regions of Spain may hide differences in the age structure of the populations, or in the balance between a much higher incidence of the disease in the Canary Islands [4], as well as a much higher rate of diabetes-related mortality than in the rest of Spain [5].

The higher diabetes-related mortality in the Canary Islands is not related to differences in the clinical management of the disease, as the use of medications at the primary care level is no less appropriate than in other countries [6], and hospital referrals, when indicated, are not used any less appropriately than in other regions of Spain [7]. Other studies have also shown that people in the Canary Islands with diabetes maintain unhealthy lifestyle habits [8], but that this is similar to that observed in other populations [9–12].

In contrast, the incidence of renal dialysis for diabetes has been found to be much higher in the Canary Islands than in the rest of Spain, Europe, or North America [13]. The incidence of lower limb amputation secondary to diabetes in the Canary Islands (319.7/105 inhabitants) is also the highest in Spain [14].

The aims of this study were to compare diabetes-related mortality rates in the Canary Islands with those of other Spanish populations aged 35–74 years, in 1981, 1991, 2001, and 2011, and to compare the prevalence of diabetes and its associated risk factors in different regions of Spain in recent years.

2. Methods

2.1. Official mortality data

National statistics on the numbers of deaths from diabetes and official mortality rates were obtained from the National Epidemiology Centre of the Instituto de Salud Carlos III in Madrid [5]. The population of different age groups and regions was obtained from the National Statistics Institute [15].

2.2. Population-based cross-sectional studies

The DARIOS study consisted of 11 Spanish cross-sectional studies, with an average response rate of 73%, in people aged 35–74 years that were pooled to create a total sample of 28,887 study participants; the methodology has been described in detail elsewhere [2]. Pooled analysis of this total sample with data from these 11 population-based studies in 10 different regions of Spain (Andalusia, Balearic Islands, Canary Islands, Castile-León, Castile-La Mancha, Catalonia, Extremadura, Madrid, Murcia, and Navarre) dating from 2000 onwards was used for the present study. The DARIOS study was approved by the Clinical Research Ethics Committee of the Parc de Salut Mar in Barcelona (authorization no. 2009/3640), and all participants provided written informed consent prior to taking part.

Questionnaire-guided interviews were conducted in participants about previous diagnoses and treatment of diabetes, arterial hypertension, and dyslipidemia. Physical examinations were carried out to measure blood pressure, weight, and height; body mass index (BMI) was used to define obesity ($BMI \geq 30\ kg/m^2$), and hypertension was recorded if blood pressure was $\geq$140/90 mmHg. Blood samples were obtained after the participant had refrained from eating or drinking for more than 10 h. All laboratory analysis was performed at local facilities in fresh blood or unthawed aliquots of serum that had been stored at −80 °C. Triglycerides (TG), glucose, and total cholesterol were measured with enzymatic assays, and high-density lipoprotein cholesterol (HDLc) was measured with a direct selective detergent method.

The prevalence of diabetes was estimated as plasma glucose values ≥126 mg/dL or cases of known diabetes (i.e., previously diagnosed diabetes). Impaired fasting glucose (IFG) was recorded in participants who had not been diagnosed as having diabetes but who had a fasting glucose concentration between 100 and 125 mg/dL. Dyslipidemia was defined as total cholesterol ≥240 mg/dL or known (i.e. previously diagnosed) dyslipidemia. A ratio of TG/HDLc > 3 was used as an indicator of insulin resistance (IR) [16,17]. In participants with diabetes, dyslipemia, and hypertension, it was accepted that their disease was controlled when they had treatment and they showed, respectively, glycemia < 130 mg/dL, total cholesterol < 240 mg/dL, and blood pressure < 140/90 mmHg.

Metabolic syndrome was defined as the presence of at least three of the following five criteria: (1) elevated fasting glucose (≥100 mg/dL) or antidiabetic treatment with insulin or oral antidiabetics; (2) elevated systolic (≥130 mmHg) or diastolic (≥85 mmHg) blood pressure, or antihypertensive treatment; (3) HDLc values <40 mg/dL (men) or <50 mg/dL (women); (4) TG ≥150 mg/dL; and (5) waist circumference ≥102 cm (men) or ≥88 cm (women).

2.3. Statistical analysis

Crude mortality rates per 10^5 inhabitants in age from 35 to 74 years were age-adjusted to the European population in order to get age-standardized mortality rates by means of direct standardization. Standardized mortality rate ratios (SRR) and their 95% confidence intervals ($CI_{95\%}$) were calculated with the Open-epi program, which uses conditional maximum likelihood estimates (http://www.openepi.com). These rates were compared with the mid-P exact test.

In the cross-sectional study, for each age group we report the absolute frequency, prevalence (%) and $CI_{95\%}$. To identify possible significant differences between the Canary Islands and other regions we used the chi-squared test in each group, or Fisher's exact test when necessary. Tables 1 and 2 also report the total numbers of individuals (n) from the Canary Islands and other regions in Spain that were included in the analysis for each variable.

Although the statistical methods in the DARIOS study have been described in detail [2], the overall prevalence of each risk factor was calculated using a combination of estimates from each regional study based on the DerSimonian–Laird method for random effects models to take differences in sample sizes into account. The coefficient of variation was estimated to determine variability in the prevalence of each risk factor among the studies included, and the percent deviation of each study from the mean of all studies was calculated. Concordance between laboratory determinations in serum and the reference laboratory values was measured with the coefficient of determination R^2, the intraclass correlation coefficient, and Bland–Altman plots. When necessary, a Deming regression line was fitted and used to correct the original values. All analyses were done with R statistical software (R Foundation for Statistical Computing, Vienna, Austria; version 2.10).

3. Results

3.1.1. Diabetes-related mortality rates

In the early 1980s the mortality rates for diabetes in the Canary Islands ($33/10^5$ in men and $43/10^5$ in women) were the highest in Spain, with a maximum SRR of 3.3 ($CI_{95\%}$ = 1.7–7.0; $p < 0.001$) in men versus Navarre, and 2.5 ($CI_{95\%}$ = 1.5–4.5; $p < 0.001$) in women versus Madrid (Table 3). By the beginning of the current decade in 2011, mortality rates in the Canary Islands had worsened in men ($38.3/10^5$), with a maximum SRR of 6.3 ($CI_{95\%}$ = 2.8–16.5; $p < 0.001$) in compared with Madrid. Mortality had improved for women in the Canary Islands in 2011 ($18.7/10^5$), but not as much as in other regions: compared with the rest of Spain, the maximum SRR had worsened compared with Madrid and was 9.5 ($CI_{95\%}$ = 2.6–60.4; $p < 0.001$) (Table 3). In 2012, the last year for which data were available, the excess mortality due to diabetes in the Canary Islands compared with the rest of Spain was first apparent at the age of 45 years, with an SRR of 2.1 ($CI_{95\%}$ = 1.0–3.8; $p < 0.05$) in the 45–54 age group, 4.0 ($CI_{95\%}$ = 2.4–6.5; $p < 0.001$) in the 55–64 age group, and 3.1 for the 65–74 age group ($CI_{95\%}$ = 2.3–4.1).

The evolution of diabetes-related mortality showed a sustained decrease from 1981 to 2011 as an overall trend in nine of the 10 regions analyzed both in men (Fig. 1A) and in women (Fig. 1B). The only community that did not follow this trend consistently was the Canary Islands men (Fig. 1A).

3.1.2. Prevalence of diabetes and associated risk factors

In the DARIOS study, we analyzed 28,887 individuals from 10 of the regions in Spain, approximately 70% of the general population. Diabetes was more prevalent in the Canary Islands population aged under 65 years (Table 1A). Obesity and hypertension (Table 1B and C) were also more prevalent in the Canary Islands in age groups up to 65 years, whereas dyslipidemia was more prevalent only in the 35–44 age group (Table 1D; $p < 0.05$). Metabolic syndrome, which comprises these factors, was also significantly more prevalent in the Canary Islands in all age groups (Table 1E). However, tobacco smoking was less prevalent in the Canary Islands than in Spain in the 35–44 (35.3% vs 38.1%; $p < 0.05$), 45–54 (25.2% vs 32.5%; $p < 0.001$), and 55–64 (14.3% vs 19.2%; $p < 0.001$) age groups. The prevalence of IFG increased from 15% in the 35–44 age group to 42% in the 65–74 age group, although there were no significant differences compared with the population sample for the rest of the country. In contrast, IR was more frequent in the Canary Islands than in the rest of Spain in all age groups (Table 1F; $p < 0.001$). Stratification by the presence or absence of obesity showed that in all age groups, IR was

Table 1 – Distribution of diabetes prevalence, insulin resistance, and cardiovascular risk factors in the Canary Islands and the rest of Spain. Absolute and relative frequencies are shown for each age group.

	Canary Islands	Spain		Canary Islands	Spain		Canary Islands	Spain		Canary Islands	Spain
	A. Diabetes			B. Obesity			C. Hypertension			D. Dyslipidemia	
Age (years)	$n = 4704$	$n = 24044$	Age	$n = 4689$	$n = 24054$	Age	$n = 4705$	$n = 24045$	Age	$n = 4706$	$n = 23973$
35–44	90 (5.1%)	210 (3.6%)†	35–44	394 (22.3%)	989 (16.7%)‡	35–44	403 (22.8%)	1030 (17.5%)‡	35–44	531 (30.1%)	1591 (27.2%)*
45–54	184 (12.9%)	602 (9.9%)†	45–54	538 (38.1%)	1550 (25.5%)‡	45–54	672 (47.3%)	2219 (36.6%)‡	45–54	607 (42.7%)	2708 (44.7%)
55–64	315 (23.4%)	1193 (18.4%)‡	55–64	584 (43.5%)	2204 (34.0%)‡	55–64	855 (63.6%)	3858 (59.3%)†	55–64	749 (55.6%)	3617 (55.8%)
65–74	51 (29.7%)	1454 (26%)	65–74	57 (33.3%)	2056 (36.9%)	65–74	119 (69.2%)	4187 (74.8%)	65–74	102 (59.3%)	3166 (56.8%)
	E. Metabolic syndrome			F. Insulin resistance			G. Insulin resistance in subjects with obesity			H. Insulin resistance in subjects without obesity	
Age (years)	$n = 4715$	$n = 24172$	Age	$n = 4042$	$n = 20246$	Age	$n = 1241$	$n = 5103$	Age	$n = 2785$	$n = 15052$
35–44	346 (19.5%)	809 (13.6%)‡	35–44	457 (27.5%)	1163 (21.1%)‡	35–44	158 (44.8%)	373 (41.8%)	35–44	299 (22.9%)	784 (17.0%)‡
45–54	530 (37.2%)	1489 (24.4%)‡	45–54	403 (32.7%)	1251 (23.3%)‡	45–54	178 (40.9%)	449 (36.1%)	45–54	223 (28.3%)	794 (19.3%)‡
55–64	652 (48.4%)	2417 (37.0%)‡	55–64	329 (32.1%)	1239 (23.6%)‡	55–64	151 (36.0%)	519 (32.7%)	55–64	177 (29.4%)	714 (19.6%)‡
65–74	90 (52.3%)	2432 (43.3%)*	65–74	45 (37.2%)	905 (22.0%)‡	65–74	17 (51.5%)	390 (28.3%)†	65–74	28 (32.2%)	508 (18.8%)†

* $p < 0.05$.
† $p < 0.01$.
‡ $p < 0.001$.

Table 2 – Distribution of awareness, treatment, and control of cardiovascular risk factors in the Canary Islands and the rest of Spain. Absolute and relative frequencies are shown for each age group.

	Canary Islands	Spain		Canary Islands	Spain		Canary Islands	Spain
A. Undetected diabetes			B. Treated diabetes			C. Controlled diabetes		
Age (years)	n = 640	n = 3459	Age (years)	n = 640	n = 3459	Age (years)	n = 639	n = 3447
35–44	15 (16.7%)	59 (28.1%)	35–44	27 (30%)	33 (15.7%)†	35–44	45 (50%)	99 (47.1%)
45–54	35 (19%)	152 (25.2%)	45–54	75 (40.8%)	175 (29.1%)†	45–54	78 (42.4%)	244 (40.5%)
55–64	50 (15.9%)	203 (17%)	55–64	160 (50.8%)	521 (43.7%)*	55–64	104 (33.1%)	458 (38.6%)
65–74	5 (9.8%)	211 (14.5%)	65–74	23 (45.1%)	758 (52.1%)	65–74	21 (41.2%)	534 (36.8%)
D. Undetected dyslipidemia			E. Treated dyslipidemia			F. Controlled dyslipidemia		
Age (years)	n = 1989	n = 11082	Age (years)	n = 1989	n = 11082	Age (years)	n = 1986	n = 11047
35–44	107 (20.2%)	531 (33.4%)‡	35–44	97 (18.3%)	157 (9.9%)‡	35–44	277 (52.4%)	592 (37.3%)‡
45–54	119 (19.6%)	775 (28.6%)‡	45–54	192 (31.6%)	570 (21%)‡	45–54	290 (47.8%)	956 (35.5%)‡
55–64	100 (13.4%)	827 (22.9%)‡	55–64	377 (50.3%)	1283 (35.5%)‡	55–64	418 (55.9%)	1677 (46.5%)‡
65–74	11 (10.8%)	688 (21.7%)*	65–74	63 (61.8%)	1479 (46.7%)†	65–74	58 (56.9%)	1688 (53.5%)
G. Undetected hypertension			H. Treated hypertension			I. Controlled hypertension		
Age (years)	n = 2045	n = 11220	Age (years)	n = 2045	n = 11220	Age (years)	n = 1990	n = 11142
35–44	176 (43.7%)	459 (45%)	35–44	107 (26.6%)	181 (17.7%)‡	35–44	116 (29.9%)	325 (32.3%)
45–54	233 (34.7%)	901 (41%)†	45–54	300 (44.7%)	735 (33.4%)‡	45–54	180 (27.6%)	561 (25.8%)
55–64	271 (31.8%)	1226 (32%)	55–64	464 (54.4%)	1930 (50.3%)*	55–64	183 (22%)	950 (24.9%)
65–74	28 (23.7%)	1200 (28.8%)	65–74	72 (61%)	2486 (59.7%)	65–74	26 (22%)	967 (23.3%)

* $p < 0.05$.
† $p < 0.01$.
‡ $p < 0.001$.

significantly more prevalent in non-obese people in the Canary Islands (Table 1G and H).

The data for factors directly related with healthcare showed that awareness, treatment and control of diabetes, hypertension, and dyslipidemia either did not differ between the Canary Islands and the rest of Spain, or reflected more favorably on the quality of care received by the Canary Islands population (Table 2).

Table 3 – Age standardized mortality rates (95% CI) for diabetes per 10^5 inhabitants in 10 Spanish communities.

	Year	1981	1991	2001	2011
Women	Canary Islands	43.12 (34.92–51.33)	42.37 (34.93–49.8)	19.11 (14.8–23.42)	18.72 (15.01–22.44)
	Andalusia	36.14 (33.04–39.25)	22.74 (20.45–25.03)	13.22 (11.62–14.82)	4.56 (3.65–5.47)
	Balearic Islands	22.03 (14.85–29.21)	16.07 (10.22–21.91)	11.97 (7.41–16.54)	4.1 (1.67–6.52)
	Castile-León	17.98 (14.9–21.05)	9.56 (7.37–11.74)	6.55 (4.77–8.33)	4.11 (2.67–5.55)
	Cast. La Mancha	25.87 (21.23–30.5)	17.14 (13.56–20.73)	8.6 (6.12–11.07)	6.03 (3.93–8.13)
	Catalonia	19.42 (17.16–21.68)	13.6 (11.86–15.33)	7.9 (6.64–9.17)	4.32 (3.41–5.22)
	Extremadura	27.33 (21.41–33.25)	23.55 (18.09–29)	12.97 (9.14–16.79)	5.32 (2.69–7.95)
	Madrid	16.74 (14.25–19.23)	9.03 (7.38–10.69)	4.71 (3.59–5.83)	2.27 (1.56–2.99)
	Murcia	33.21 (25.28–41.13)	19.94 (14.51–25.37)	13.5 (9.38–17.62)	6.16 (3.58–8.74)
	Navarre	19.58 (11.84–27.32)	16.11 (9.59–22.62)	8.33 (3.68–12.98)	4.57 (1.4–7.75)
Men	Canary Islands	32.73 (25.1–40.37)	33.92 (26.78–41.06)	31.11 (25.35–36.87)	38.27 (32.81–43.73)
	Andalusia	26.03 (23.08–28.97)	21.05 (18.64–23.45)	17.06 (15.06–19.06)	8.82 (7.49–10.15)
	Balearic Islands	19.09 (12–26.17)	16.64 (10.2–23.08)	10.87 (6.2–15.55)	8.03 (4.58–11.47)
	Castile-León	13.17 (10.26–16.07)	10.1 (7.73–12.48)	10.55 (8.18–12.91)	9.57 (7.3–11.83)
	Cast. La Mancha	18.68 (14.39–22.98)	13.81 (10.27–17.35)	14.3 (10.82–17.79)	10.22 (7.35–13.08)
	Catalonia	17.67 (15.26–20.09)	15.19 (13.16–17.22)	13.05 (11.29–14.8)	9.55 (8.13–10.98)
	Extremadura	20.77 (14.93–26.61)	14.29 (9.64–18.94)	11.74 (7.59–15.89)	10.56 (6.71–14.42)
	Madrid	13.62 (11.02–16.22)	9.71 (7.75–11.68)	6.99 (5.49–8.48)	5.79 (4.53–7.04)
	Murcia	24.93 (17.39–32.47)	22.02 (15.69–28.35)	16.82 (11.82–21.81)	6.46 (3.69–9.23)
	Navarre	10.36 (4.23–16.48)	18.29 (10.76–25.82)	12.14 (6.47–17.81)	8.88 (4.22–13.53)

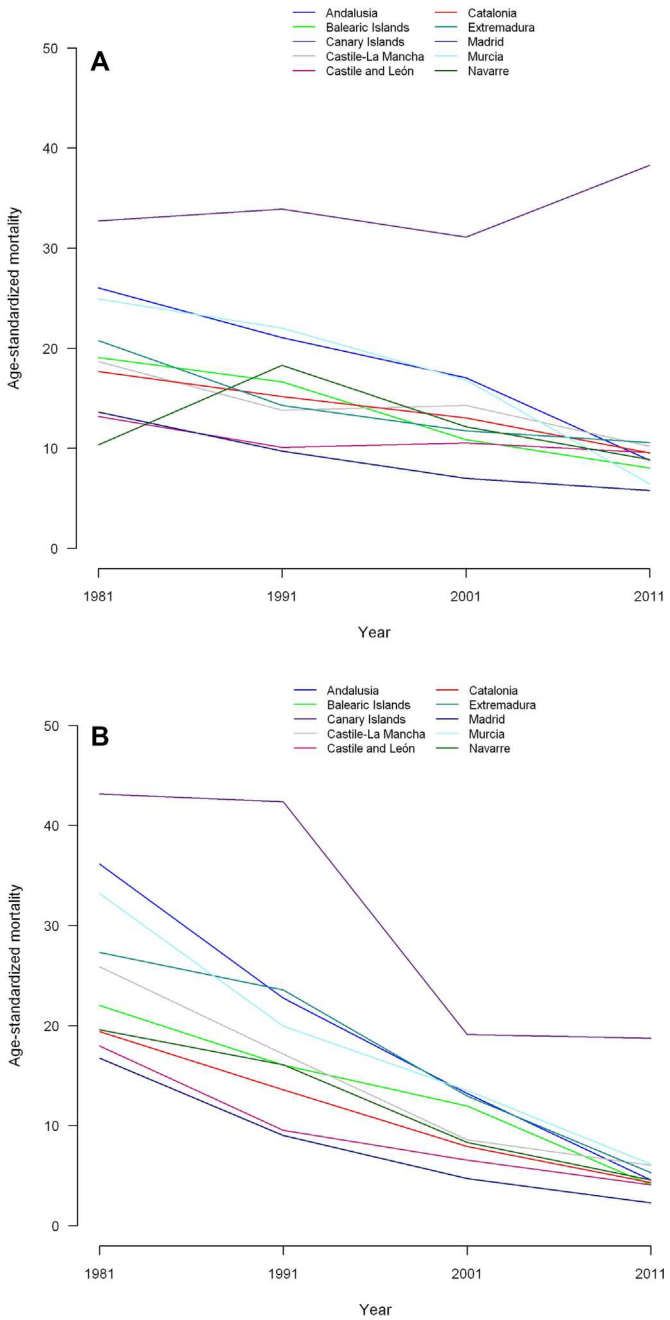

Fig. 1 – Evolution of diabetes-related mortality in 10 regions in Spain over the last four decades (age-standardized mortality rates per 10^5 inhabitants). (A) Men, (B) Women.

4. Conclusion

The diabetes-related mortality rate has been higher in the Canary Islands than in the rest of Spain for several decades, and the current trend over the last several years is alarming, particularly in men. From 1980 to 2000, diabetes-related mortality declined, but since the start of the twenty-first century mortality has increased in this region while continuing to decrease in all other parts of Spain included on our analysis.

To our knowledge, no previous study has compared the prevalence of diabetes stratifying by age groups between the Canary Islands and Spain. We show that the prevalence of diabetes in the Canary Islands is higher than in the rest of Spain in all age groups, although the difference is significant only in those aged less than 65 years. The combination of higher prevalence and higher incidence [4] together with the strikingly high mortality rate clearly make diabetes a serious public health problem in the Canary Islands. The higher mortality in men is at least in part attributable to a much higher proportion of unknown diabetes and individuals who do not receive regular treatment [8].

We cannot establish a cause and effect relationship with any epidemiological phenomena during the twenty-first century that might explain the upturn in diabetes-related mortality in the islands. However, an ecological analysis points to the outbreak of an epidemic wave of obesity in the Canary Islands around this time, with an increase in prevalence from 18% in 1996 [18] to 28% from 2000 to 2005 [19]. With all due caution regarding speculations of this nature, it is worth noting that in this population, already characterized by a high death rate from diabetes, the appearance of the epidemic of obesity was also associated with an abrupt increase in diabetes-related mortality rate. This epidemic, mainly associated with changes in food intake, started in the USA at the end of the 1980s [20] and reached European countries during the 1990s. Some Spanish regions, like the Canary Islands and Andalusia, often visited by millions of tourists from North-Western Europe, have reached a high prevalence of obesity [2]. However, an increase in diabetes-related mortality has only been seen in the Canary Islands.

The higher prevalence of obesity in the Canary Islands has not yet affected those over 64 years, possibly because this generation has not been impacted so strongly by changes in food intake. A finding likely to be related with this situation is that the prevalence of hypertension in the islands is only higher than the national average in people younger than 65 years. This distribution of obesity and hypertension among age groups parallels the distribution of diabetes as detailed above, and is consistent with current knowledge regarding the association of these three problems, which frequently co-occur to give rise to metabolic syndrome [21]. As the population cohort with a high prevalence of obesity ages, diabetes-related mortality is likely to increase among Canary Island inhabitants older than 64 years, and is expected to exacerbate the upturn in mortality rate.

Although there are no studies of obesity in the Canary Islands dating from the early 1980s, it can probably be assumed that as in Spain, Europe, and the USA [22], its prevalence was much lower than now, and the problem was far from reaching epidemic proportions. However, we found that diabetes-related mortality in the Canary Islands at that time was already higher than in other parts of Spain. These results indicate that the disease could also be more severe in this population, with a high incidence of renal dialysis [13] as well as a high incidence of lower limb amputation secondary to diabetes [14].

It is worth noting that although the population is considered phenotypically Caucasian, its ethnic origins differ compared with the rest of Spain. Canary Island inhabitants are descendants of a mixture of aboriginal inhabitants from northern Africa and Spanish colonists who arrived in the fifteenth century and later [23]. In populations of African ethnic origin a number of genetic markers have been identified as being associated with an unfavorable prognosis for kidney function in diabetes [24–26]. This association has not yet been studied in the Canary Islands population despite the finding that diabetes shows a high likelihood of end-stage renal disease in this population [13]. Similarly, we found that IR was more prevalent in all age groups in the Canary Islands than in other parts of Spain—a problem that may be inherent to this population, and which is independent of obesity. Increased IR may be related to diabetes prevalence and mortality rates in the Canary Islands decades before the obesity epidemic; previous studies in other countries have shown the effect of increased IR (high TG/HDL ratio) for cardiovascular diseases and mortality, irrespective of BMI [27]. It would clearly be advisable to investigate genetic markers associated with IR given that IR is more common in some African ethnic groups [28,29] and in some remote ethnic groups that were genetically isolated for centuries [30]. In any case it appears clear that the prevalence of IR is associated with the increased prevalence of metabolic syndrome even among inhabitants older than 64 years in the Canary Islands, even though the prevalence of obesity, diabetes, and hypertension in the oldest members of our study population was not significantly higher than in the rest of the population of Spain.

Our analysis of indicators of the quality of healthcare shows that compared with other regions in Spain, no deficiencies are apparent in healthcare provided in the Canary Islands. In terms of awareness, treatment, and control of diabetes and its associated diseases, there is no evidence that the high mortality rate is connected in any way to a lower quality of healthcare. The large number of studies of diabetes [1,4,6–8,13,14,19] is in itself an indicator that healthcare professionals in the islands have taken a keen interest in this problem. In connection with the unhealthy lifestyle habits reported for Canary Islands patients with diabetes [8], earlier studies have noted that this appears to be a common factor among patients in other populations [9–12]. As in other settings, the Canary Islands health system has introduced notable improvements in the diagnosis and treatment of diabetes in the last 20 years (e.g., integrated healthcare programs, patient education, better control of blood pressure, screening for diabetic retinopathy, microproteinuria, and abnormal levels of glycated hemoglobin, the massive use of statins and better control of lipid levels, new antidiabetic drugs, etc.). These measures all appear to have helped reduce the rate of complications and morality in the rest of Spain as well as in Europe [31] and North America [32], but have been apparently less effective in the Canary Islands.

Among the limitations of our study we accept that we cannot completely rule out differences between regions in the accuracy of death certification, but this is unlikely the reason for the high mortality in the Islands; the higher mortality we observed has been noted by different generations of doctors. The mortality data from death records are filled in by doctors, and the procedure has not changed for decades. Furthermore, there is additional evidence that the mortality differences are real: we mentioned above a very high incidence of renal dialysis for diabetes in the Canary Islands [13], and a high incidence of lower limb amputation secondary to diabetes [14]. Another limitation is the fact that the DARIOS study does not include all regions in Spain. However, the sample is representative of 70% of the general population aged between 35 and 74 years, and we have studied the largest sample published to date of the general population of the Canary Islands; moreover, our analysis involves the largest population sample reported to date for epidemiological research on diabetes in Spain. The cross-sectional design limits the extent to which causal relationships can be established, but is nonetheless appropriate for comparing prevalences across age groups as well as in the general population as a whole. We acknowledge the limitations of our ecological analysis of the associations between population-based mortality and the prevalence of risk factors in our sample of the population. However, this design offers an efficient approach for large-scale studies and is suitable for the purpose of suggesting hypotheses to explain the serious health problem currently faced by the Canary Islands.

A final limitation worth noting is that, although we studied some factors directly related to healthcare, we did not analyze socio-economic differences between regions; nevertheless, it is well known that the per capita income in the Canary Islands is no lower than in other regions such as Andalusia, Murcia, Castile La Mancha, or Extremadura [33].

To conclude, the Canary Islands diabetes-related mortality and prevalence rates are the highest in the Spanish regions examined in the present study. A recent unexpected rise in diabetes-related mortality, particularly in men, that breaks the decreasing trend of past decades prompts for a rapid public health policy response. The high prevalence of IR and high diabetes-related mortality rate of this island region warrant comparative investigation of the genetic background that may be associated with this particular epidemiologic situation.

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Conflict of interest statement

The authors have no relevant conflict of interest to disclose.

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