Trends in the prevalence of diabetes and impaired fasting glucose in association with obesity in Iran: 2005–2011

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ABSTRACT

Aims: To estimate the prevalence and trends of diabetes mellitus (DM) and impaired fasting glucose (IFG), 2005–2011, and to determine the contribution of obesity to DM prevalence.
Patients and methods: Data from Surveillance of Risk Factors of Non-communicable Diseases (SuRFNCD) conducted in 2005, 2007, and 2011 were gathered. DM was defined as presence of self-reported previous diagnosis or a fasting plasma glucose (FPG) ≥ 7 mmol/L. IFG was diagnosed with FPG levels between 5.6 and 6.9 mmol/L. Prevalence rates for 2011 and trends for 2005–2011 were determined by extrapolating survey results to Iran's adult population. Population attributable fraction (PAF) of obesity was also calculated.
Results: In 2011, IFG and total DM prevalence rates were 14.60% (95%CI: 12.41–16.78) and 11.37% (95%CI: 9.86–12.89) among 25–70 years, respectively. DM was more common in older age ($p < 0.0001$), in women ($p = 0.0216$), and in urban-dwellers ($p = 0.0001$).

In 2005–2011, trend analysis revealed a 35.1% increase in DM prevalence (OR: 1.04, 95%CI: 1.01–1.07, $p = 0.011$); albeit, IFG prevalence remained relatively unchanged (OR: 0.98, 95%CI: 0.95–1.00, $p = 0.167$). In this period, DM awareness improved; undiagnosed DM prevalence decreased from 45.7% to 24.7% ($p < 0.001$). PAF analysis demonstrated that 33.78%, 10.25%, and 30.56% of the prevalent DM can be attributed to overweight (BMI ≥ 25 kg/m^2), general obesity (BMI ≥ 30 kg/m^2), and central obesity (waist circumference ≥ 90 cm), respectively. Additionally, the DM increase rate in 2005–2011, was 20 times higher in morbidly obese compared with lean individuals.
Conclusion: More than four million Iranian adults have DM which has increased by 35% over the past seven years, owing in large part, to expanding obesity epidemic.

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1. Introduction

Diabetes mellitus (DM) is a global public health concern that is reaching staggering proportions. Based on a recent report by the International Diabetes Federation (IDF), DM affected 366 million people in 2011, and this number is expected to rise to 552 million by 2030 [1]. The IDF Diabetes Atlas also stated that the Middle East and North Africa (MENA) region currently has the highest regional prevalence of DM, and by 2030 it is expected to have the second largest proportional increase after Africa [2]. In accordance with this data, we have reported a marked increase in the national prevalence of DM from 7.7% to 8.7% over a three year period (2005–2007) [3]. Upward trends have also been reported in other developing and developed countries. Between 1993 and 2003, the DM prevalence in China almost tripled (1.9% vs. 5.6%) [4].

In the UK, the DM prevalence rose from 2.8% to 4.3% over a 10-year period (1996–2005) [5]. Similarly, between 1995 and 2005, the proportion of Canadian adults with DM increased by 69% (5.2% vs. 8.8%) [6].

In 2007, DM accounted for $174 billion of health spending in the US [7]. In Iran, the annual direct costs of DM were estimated to be $590 million in 2009 [8]. Indeed, the burden of DM is not limited to direct health care expenditure; indirect costs caused by loss of productivity and premature mortality in adults of working-age also contribute to this global calamity, which is reaching catastrophic proportions [9]. In addition to the health resources allocated for DM, an abundance of resources is directed toward the management of impaired fasting glucose (IFG), a pre-diabetes state. Subjects with IFG, compared to healthy individuals, have higher medical costs, which are largely due to cardiovascular complications [10]. In addition, it has been estimated that as many as 70% of individuals diagnosed with IFG, will eventually progress to DM [11]. Physical inactivity, rapid economic transition and urbanization, excessive caloric intake and more importantly, obesity, are closely associated with DM. With an accelerated increase in the obesity prevalence in the past 20 years, it is postulated that developing countries will soon face an upsurge in DM [12]. The prevalence of obesity in Iran has increased from 13.6% in 1999 to 22.3% in 2007 [13]. Obesity, either in general or central forms, is believed to be a substantial risk factor for the development of type 2 DM [14]. One unit increase in body mass index (BMI) has been shown to raise the incidence of DM by 25% [15].

To provide a better understanding of the prevalence of non-communicable diseases and their associated risk factors, the Surveillance of Risk Factors of Non-communicable Diseases (SuRFNCD) was initiated in Iran, in 2005. In the present study, we report on the nation-wide prevalence of IFG and DM, derived from Iran's 2011 SuRFNCD. Moreover, we delve into secular trends of DM observed over the 2005–2011 period. Finally, since obesity confers substantial risk for the development of DM, the contributions of; overweight, general, and central obesity, to the prevalence of DM among Iranian adults are investigated.

2. Methods

2.1. SuRFNCD-2011

This randomized multistage cluster sampling scheme was designed to select a representative sample of non-hospitalized and non-institutionalized Iranian individuals, 6–70 years-of-age. Furthermore, nomadic tribes (population according to 2011 national census = 56,225), who live in settlements that are not covered by the Iranian postal service, were not included. By employing a four stage sampling scheme, between May 22nd and June 20th 2011, a total of 11,867 individuals were surveyed.

At the first stage of sampling, individual counties, or a group of neighboring counties were designated as primary sampling units (PSUs). Fifty PSUs were then selected by employing the probability proportionate to size (PPS) random sampling method. In each PSU, 12 areas were selected as secondary sampling units (SSUs), in a manner similar to the previous step. In the third stage, 20 postal addresses (10-digit postal codes) within each SSU, from a framework provided by the Iran's postal service, were randomly selected. Each address was contacted and the inhabitants were registered. We hypothesized that conventional Kish tables provided by the World Health Organizations (WHO) would result in under sampling of adults ≥55 years old. Therefore, two independent sets of Kish tables for persons <55 and ≥55 years were developed. One individual was chosen from each Kish table and they were visited at their household. After three attempts, if a sampling individual was not available or refused to participate, the label 'non-response' was applied. The cluster sampling was conducted under the direction of Iran's Center for Disease Control (CDC). The final stage was carried out by trained interviewers and was supervised by 43 medical universities across the country.

At the beginning of each interview, a consent form was read by the interviewer and acceptance or refusal to participate was formally recorded. All procedures described here were conducted in accordance with the guidelines and standards laid down in the current revision of the Declaration of Helsinki. The CDC Board of Ethics also approved the study protocol. A total of 5279 adults aged 25–70, and 4759 adults aged 25–64 years, with valid responses to the DM questions and available laboratory measurements were included from the survey.

2.2. SuRFNCD-2005 and 2007

For the analysis of DM secular trends, and trends according to general and central obesity, the data from the SuRFNCD-2005 [16] and SurFNCD-2007 [3] were collected. In the SuRFNCD-2005 and -2007, 51,903 and 3342 Iranian adults aged 25–64 had questionnaires and laboratory evaluations available and therefore they were included. Despite differences in design, sampling protocols, and sample sizes, all three SuRFNCD surveys are representative of the Iranian population. The methodology employed for physical examination and laboratory measurements were similar in all three rounds and are described below.

2.3. Physical examination

Weight was measured using a portable digital scale and was recorded with one decimal digit precision (kg). Height was measured with subjects standing without socks and shoes, using inflexible measurement tapes and the reading was rounded to the nearest 0.1 cm. Body mass index (BMI) was calculated as weight in kilograms divided by height, in squared meters (kg/m^2). Waist circumference was measured mid-way around the direct line that connects the lower costal margin and anterior–superior iliac spine at the end of normal expiration, and this was recorded to the nearest 0.1 cm.

2.4. Laboratory evaluation

Sample participants aged 25 years and higher were instructed to go on an overnight fasting for 12–14 h. Blood sampling was performed the next day by trained laboratory personnel.

A 10 ml sample of venous blood was drawn from each individual according to the standard protocol and was sent to collaborating centers. At each laboratory, samples were immediately centrifuged (1500 rpm for 10 min). Fasting plasma glucose was measured with enzymatic calorimetric methods using a glucose oxidize test. All tests were performed using quality controlled commercial kits (Pars Azmun, Karaj, Iran) distributed by the CDC reference laboratory. The intra- and inter-assay coefficients of variations were 2.1% and 2.6%, respectively.

2.5. Questionnaire and definitions

Known DM was defined as responding positive to either of the following two questions: (1) 'Have you ever been told by a doctor or other health worker that you have diabetes?' (2) 'Are you currently taking oral medication or insulin for diabetes prescribed by a doctor or other health worker?' Undiagnosed DM was defined as responding 'no' to both questions, plus FPG concentrations $\geq$7 mmol/L. IFG was defined as FPG concentrations between 5.6 and 6.9 mmol/L in patients without known DM. Total DM was defined by adding known and undiagnosed DM. However, no distinction was made with respect to type 1 and type 2 DM. BMI cut-off values <25 kg/m^2, $25 \leq$ BMI < 30, and BMI $\geq$ 30 were used to define normal-weight, overweight, and general obesity, respectively. Waist circumference levels $\geq$90 cm were used as the cut-off for the diagnosis of central obesity in both sexes [17].

2.6. Statistical analysis

For analysis of the data, Stata version 11 for Windows (Stata Corporation, College Station, Texas, United States) was used. The complex survey feature of the Stata was employed to extrapolate survey participants to the 2011 adult population of Iran, adjusting for design and non-response weights. Design weight was defined as the inverse of the probability of selection for each individual in the sample, and this was calculated by multiplying the probability of each step of the survey and for the Kish tables (<55 years and $\geq$55years) by Iran's CDC. Given the methodological differences in previous rounds, design weights were only applied to SuRFNCD-2011,

and data from the 2005 and 2007 surveys were only extrapolated using non-response weights to 2011 national population. Non-response weights were therefore generated for age (10-year strata: 25–34, 35–44, 45–54, and 55–64), sex (male, female), and area of residence (urban, rural). According to Iran's 2011 national census data, 38,199,463 adults aged 25–64 years and 39,793,002 adults aged 25–70 years reside in the country [18]. With the complex sample analysis plan available, population estimates and the prevalence rate of each outcome of interest, along with their 95% confidence interval (95% CI), were calculated. The Jackknife method was used to estimate variance throughout the analyses. The Cochran–Armitage test was used to test for a trend in crude prevalence rates across age strata. Differences in outcome prevalence across binary categories (i.e., sex and area of residence) were investigated using a design-based Chi square test. Age-standardized prevalence rates for SuRFNCD-2005 and 2007 were calculated in a similar manner and by extrapolating the sample to Iran's 2011 population. The presence of a secular trend over the course of seven years was assessed using design-based logistic regression models. Odds ratios (ORs) along with 95% CI for each outcome were calculated for every one year increase in calendar year (0 for 2005, 2 for 2007, and 6 for 2011), after adjusting for age, sex, and area of residence. The contribution of obesity to the prevalence and increase in DM was investigated using design-based logistic regression. In a regression model adjusted for; age, sex, area of residence, and calendar year; ORs of overweight, general, and central obesity were calculated for total DM. Derived ORs were then placed in the following formula to calculate the population attributable fraction (PAF): PAF = $(p|1 - \text{OR}|)/\text{OR}$, where p is the prevalence of overweight/obesity. PAF for DM for instance, is the proportional reduction in DM that is expected to occur if a certain risk factor (i.e., overweight/obesity) is reduced to an alternative, lower level (i.e., normal weight). In addition, secular trends for DM were calculated across different BMI categories to investigate whether DM is increasing at different rates among lean and obese individuals.

3. Results

3.1. 2011 national estimates

National population estimates and prevalence rates for IFG, undiagnosed DM, known DM, and total DM in 2011 are presented in Table 1. About 11.4% of Iranian adults aged 25–70, that is 4.52 million, had DM. Another 5.81 million or 14.6% were diagnosed with IFG. In 2011, one out of four patients with DM was not aware of their disease status (8.7% known vs. 2.7% undiagnosed). The prevalence of IFG increased significantly with advancing age; adults in the oldest age category (56–70 years) were two times more likely to have IFG than the youngest (25–34 years). Similar trends for undiagnosed, known, and total DM were also evident (p < 0.0001, 0.0470, and <0.0001, respectively). Subjects in the oldest age strata were almost nine times more likely to have DM (29.2% in 65–70 years vs. 3.3% in 25–34 years, p < 0.0001). In other words, one out of three individuals aged 65–70 years had DM. The prevalence of DM was about 30% higher in women (12.9%

Table 1 – Prevalence of impaired fasting glucose, undiagnosed diabetes, known diabetes, and total diabetes in adult population of Iran, 2011.

	IFG			Undiagnosed diabetes			Known diabetes			Total diabetes		
	Pop. Est.	Prevalence % (95% CI)	p	Pop. Est.	Prevalence % (95% CI)	p	Pop. Est.	Prevalence % (95% CI)	p	Pop. Est.	Prevalence % (95% CI)	p
Age												
25–34	1.48	9.44 (7.21–11.67)	<0.0001	0.15	0.95 (0.42–1.47)	0.0470	0.36	2.32 (1.06–3.59)	0.0470	0.51	3.27 (1.92–4.61)	<0.0001
35–44	1.51	14.39 (11.37–17.41)		0.32	3.10 (1.43–4.77)		0.64	6.10 (4.24–7.95)		0.96	9.20 (6.54–11.85)	
45–54	1.53	20.20 (16.39–24.01)		0.28	3.66 (2.56–4.76)		1.16	15.39 (11.97–18.81)		1.44	19.05 (15.38–22.71)	
55–64	0.99	21.89 (18.60–25.18)		0.26	5.64 (4.40–6.88)		0.89	19.69 (17.18–22.20)		1.15	25.32 (22.74–27.91)	
65–70	0.30	19.28 (14.84–23.72)		0.07	4.69 (3.00–6.39)		0.39	24.48 (20.94–28.02)		0.46	29.18 (25.44–32.91)	
Sex												
Male	3.08	15.45 (12.71–18.18)	0.1485	0.56	2.80 (1.71–3.89)	0.1465	1.41	7.09 (5.22–8.96)	0.1465	1.97	9.90 (7.72–12.06)	0.0216
Female	2.72	13.74 (11.55–15.94)		0.52	2.63 (1.95–3.30)		2.03	10.23 (8.82–11.65)		2.55	12.86 (11.20–14.53)	
Residential area												
Urban	4.55	15.44 (13.00–17.89)	0.0580	0.87	2.97 (2.16–3.77)	0.4661	2.86	9.72 (8.32–11.13)	0.4661	3.73	12.69 (10.94–14.43)	0.0001
Rural	1.26	12.18 (9.16–15.20)		0.21	2.00 (1.24–2.75)		0.58	5.62 (4.20–7.04)		0.79	7.62 (5.73–9.50)	
Total	5.81	14.60 (12.41–16.78)		1.08	2.71 (2.05–3.38)		3.44	8.66 (7.47–9.84)		4.52	11.37 (9.86–12.89)	

Abbreviations: IFG, impaired fasting glucose; Pop. Est., population estimate rounded to the nearest million.

vs. 9.9%, p = 0.0216), although the same sex predilection was not observed for IFG (13.7% vs. 15.4%, p = 0.1485). Women were more likely to have their DM diagnosed than men (79.6% vs. 71.7%), although the difference did not reach statistical significance (p = 0.1465). Urban to rural ratio of total DM prevalence in Iranian adults was 3:2 (p = 0.0001). The difference was less pronounced for IFG, however (ratio: 5:4, p = 0.0580).

3.2. Seven year trends

Prevalence and trends for IFG, undiagnosed, known and total DM 2005–2011 are depicted in Table 2. Over the course of seven years, a 35.1% increase in total DM prevalence among 25–64 year-old adults was noted. This increase was independent of age, sex, and area of residence [OR for secular trend = 1.05 (1.02–1.08), p = 0.005]. In sub-population analysis, the increasing trends were only statistically significant among 45–65 years, women but not men, and urban but not rural residents (Table 2). In the 2005–2011 period, the known to undiagnosed DM ratio significantly changed; an 87.4% increment in the proportion of known DM was recorded (4.3% in 2005 vs. 8.0 in 2011, p < 0.001). Sub-population analysis revealed that the increase in awareness is consistently observed across all age strata, sex, and residential area categories (p < 0.05 for all tests).

Between 2005 and 2011, IFG prevalence remained relatively constant (15.3% in 2005 vs. 14.4% in 2011, p = 0.985). While individuals aged 25–44 years experienced a decrease in IFG rate, a modest increase of 8.0% was observed in older adults (45–65 years); albeit the findings were not statistically meaningful. Similarly, no significant trends were discovered among women/men and urban/rural categories (Table 2).

3.3. Obesity as a modifiable risk factor of DM

As demonstrated in Table 3, BMI $\geq$ 25 kg/m^2 was significantly associated with DM after controlling for; age, sex, area of residence, and secular trends (OR: 2.1, 95% CI:1.9,2.4, p < 0.0001).

Based on obtained ORs, if the adult population decreased their BMI to below normal limits, DM prevalence would decrease by one third. Similarly, general obesity (BMI $\geq$ 30 kg/m^2) was a significant predictor of total DM; elimination of obesity would reduce the prevalence of diabetes by up to 9.3%. Adults with elevated waist circumference were 2.2 times more likely to have DM (OR: 2.2, 95% CI: 2.0,2.4, p < 0.0001). Estimated PAF for central obesity was 26.7% (95% CI: 24.5, 28.7). While estimated PAFs for overweight and general obesity were larger for women, the derived PAFs for central obesity were nearly identical in both sexes.

As illustrated in Fig. 1, the rate of DM increase over seven years was about 20 times higher in morbidly obese individuals compared with their lean counterparts. A stepwise increase in DM secular trends was also evident when moving from the lean to morbidly obese categories. The prevalence of DM increased by 47.7% in centrally obese adults, this figure was almost five times higher than in those without central obesity.

4. Discussion

4.1. Prevalence of diabetes and impaired fasting glucose

In the present study a striking prevalence of DM was recorded among Iranian adults aged 25–70 years (11.4%, 95% CI: 9.9, 12.9%). Furthermore, 14.6% (95%, CI: 12.4, 16.8%) of Iranian adults were diagnosed with IFG. Conjointly, one in four Iranian adult suffers from clinically significant abnormalities in glucose metabolism placing a tremendous strain on healthcare resources.

Current estimates of DM in Iran are comparable to the results obtained from the US National Health and Nutrition Examination Survey (NHANES). In 2005–2006, a point prevalence of 12.9% was documented for adults aged 20 years and older [19]. Notwithstanding the similar crude rates for DM, the prevalence of IFG in Iranian adults is significantly lower than the rates observed in the US (14.6% vs. 25.7%). Based on available data of adults aged 20–70 years, the IDF Atlas of

Table 2 – Prevalence and trends of diabetes and impaired fasting glucose in Iranian adult population, 2005–2011.

	2005		2007		2011		Seven year change (%)	P for secular trend	Secular trend OR (95% CI)
	Pop. Est.	Prevalence % (95% CI)	Pop. Est.	Prevalence % (95% CI)	Pop. Est.	Prevalence % (95% CI)			
IFG									
Age									
25–34	1.81	11.54 (10.94–12.15)	0.96	6.09 (4.38–7.80)	1.48	9.44 (7.21–11.67)	−18.1	0.386	0.98 (0.93–1.03)
35–44	1.70	16.24 (15.57–16.91)	1.05	10.07 (8.02–12.14)	1.51	14.39 (11.37–17.41)	−11.4	0.687	0.99 (0.95–1.04)
45–54	1.41	18.69 (18.00–19.38)	1.03	13.70 (11.28–16.12)	1.52	20.20 (16.39–24.01)	+8.1	0.173	1.03 (0.99–1.08)
55–64	0.92	20.35 (19.64–21.05)	0.65	14.34 (11.82–16.86)	1.00	21.96 (18.69–25.24)	+7.9	0.077	1.03 (1.00–1.07)
Sex									
Male	3.05	15.88 (15.36–16.39)	1.99	10.39 (8.81–11.97)	2.93	15.25 (12.58–17.92)	−4.0	0.836	1.00 (0.96–1.05)
Female	2.79	14.70 (14.24–15.16)	1.70	8.94 (7.52–10.35)	2.58	13.57 (11.32–15.81)	−7.7	0.830	1.00 (0.96–1.03)
Residential area									
Urban	4.50	15.89 (15.46–16.33)	2.95	10.43 (9.09–11.77)	4.34	15.31 (12.86–17.77)	−3.6	0.826	1.00 (0.97–1.04)
Rural	1.34	13.56 (13.05–14.06)	0.74	7.48 (6.00–8.95)	1.17	11.67 (8.89–14.77)	−13.9	0.649	0.99 (0.93–1.04)
Total	5.84	15.29 (14.94–15.64)	3.69	9.67 (8.61–10.73)	5.51	14.41 (12.25–16.58)	−5.7	0.985	1.00 (0.97–1.0.4)
Undiagnosed diabetes									
Age									
25–34	0.30	1.93 (1.67–2.19)	0.35	2.22 (1.19–3.26)	0.15	0.95 (0.42–1.47)	−50.8	<0.001	0.76 (0.66–0.86)
35–44	0.36	3.41 (3.08–3.74)	0.40	3.81 (2.50–5.12)	0.32	3.10 (1.43–4.77)	−9.09	0.028	0.89 (0.80–0.99)
45–54	0.42	5.50 (5.09–5.90)	0.28	3.71 (2.45–4.98)	0.28	3.66 (2.56–4.76)	−33.4	<0.001	0.84 (0.79–0.90)
55–64	0.30	6.63 (6.19–7.07)	0.20	4.38 (2.91–5.86)	0.26	5.64 (4.40–6.88)	−14.9	0.001	0.90 (0.86–0.96)
Sex									
Male	0.70	3.65 (3.40–3.90)	0.62	3.23 (2.35–4.11)	0.54	2.82 (1.72–3.92)	−22.7	0.006	0.87 (0.79–0.96)
Female	0.68	3.55 (3.32–3.78)	0.61	3.19 (2.28–4.10)	0.47	2.45 (1.77–3.12)	−31.0	<0.001	0.85 (0.80–0.91)
Residential area									
Urban	1.09	3.85 (3.63–4.06)	0.92	3.23 (2.44–4.02)	0.82	2.88 (2.08–3.68)	−25.2	<0.001	0.86 (0.81–0.91)
Rural	0.29	2.89 (2.66–3.18)	0.31	3.15 (2.18–4.11)	0.19	1.92 (1.14–2.70)	−33.6	<0.001	0.86 (0.80–0.92)
Total	1.38	3.60 (3.44–3.77)	1.23	3.21 (2.57–3.84)	1.01	2.63 (1.97–3.30)	−26.9	<0.001	0.86 (0.82–0.91)
Known diabetes									
Age									
25–34	0.18	1.15 (0.95–1.35)	0.10	0.66 (0.12–1.20)	0.36	2.32 (1.06–3.59)	+101.7	<0.001	1.32 (1.16–1.51)
35–44	0.36	3.46 (3.13–3.79)	0.43	4.10 (2.73–5.44)	0.64	6.10 (4.24–7.95)	+76.3	0.028	1.13 (1.01–1.25)
45–54	0.58	7.64 (7.16–8.11)	0.87	11.58 (9.30–13.86)	1.16	15.39 (11.97–18.81)	+101.4	<0.001	1.19 (1.11–1.27)
55–64	0.51	11.26 (10.69–11.81)	0.88	19.26 (16.43–22.08)	0.89	19.61 (17.10–22.13)	+74.2	0.001	1.11 (1.05–1.17)
Sex									
Male	0.65	3.38 (3.15–3.60)	0.98	5.12 (4.18–6.06)	1.25	6.52 (4.49–8.55)	+92.9	0.006	1.15 (1.04–1.26)
Female	0.98	5.16 (4.91–5.42)	1.30	6.84 (5.77–7.90)	1.80	9.48 (8.07–10.89)	+83.7	<0.001	1.17 (1.10–1.25)
Residential area									
Urban	1.37	4.82 (4.60–5.03)	1.88	6.64 (5.74–7.53)	2.56	9.04 (7.56–10.52)	+87.6	<0.001	1.16 (1.09–1.23)
Rural	0.26	2.68 (2.47–2.89)	0.40	4.07 (3.07–5.07)	0.49	5.00 (3.64–6.36)	+86.6	<0.001	1.17 (1.09–1.25)
Total	1.63	4.27 (4.10–4.44)	2.28	5.97 (5.26–6.67)	3.05	8.00 (6.77–9.22)	+87.4	<0.001	1.16 (1.10–1.22)
Total diabetes									
Age									
25–34	0.48	3.08 (2.75–3.41)	0.45	2.88 (1.72–4.04)	0.51	3.27 (1.91–4.63)	+6.2	0.725	1.01 (0.94–1.10)
35–44	0.72	6.87 (6.41–7.33)	0.83	7.91 (6.06–9.75)	0.96	9.20 (6.48–11.92)	+33.9	0.084	1.05 (0.99–1.11)
45–54	0.99	13.14 (12.54–13.74)	1.15	15.29 (12.73–17.79)	1.44	19.05 (15.31–22.78)	+45.0	0.002	1.08 (1.03–1.12)
55–64	0.81	17.88 (17.21–18.56)	1.07	23.64 (20.60–26.68)	1.15	25.25 (22.65–27.86)	+41.2	<0.001	1.07 (1.04–1.09)
Sex									
Male	1.35	7.03 (6.70–7.36)	1.60	8.35 (7.10–9.60)	1.79	9.34 (6.96–11.72)	+32.9	0.112	1.04 (0.99–1.10)
Female	1.65	8.72 (8.38–9.05)	1.91	10.03(8.65–11.40)	2.27	11.93 (10.27–13.60)	+36.8	0.002	1.05 (1.02–1.08)
Residential area									
Urban	2.45	8.67 (8.37–8.96)	2.80	9.87 (8.70–11.02)	3.38	11.92 (10.07–13.78)	+37.5	0.003	1.05 (1.02–1.09)
Rural	0.55	5.57 (5.26–5.88)	0.71	7.22 (5.82–8.59)	0.68	6.92 (5.07–8.83)	+24.2	0.421	1.02 (0.97–1.08)
Total	3.00	7.87 (7.64–8.10)	3.51	9.19 (8.26–10.11)	4.06	10.63 (9.05–12.21)	+35.1	0.005	1.05 (1.02–1.08)

Abbreviation: IFG, impaired fasting glucose; Pop. Est., population estimate, rounded to the nearest million.

Diabetes [20] estimated a point prevalence of 9.33% for DM in 2011, and it has also predicted that this figure would rise to 13.15% by 2030. Figures observed herein are significantly higher than IDF estimates, and most likely reflect the accelerated growth of the DM epidemic in the Middle East and North Africa (MENA) region. DM prevalence in Iran is significantly higher than its neighboring countries Pakistan (6.7% for 2007) [21] and Turkey (7.2%, for 1997–1998) [22]. On the

Table 3 – Population attributable fraction of obesity for diabetes in Iranian adult population, 2005–2011.			
	OR (95% CI)	*p*	PAF
Overweight/general obesity (BMI ≥ 25 kg/m²)			
Male	2.11 (1.77–2.51)	<0.0001	27.14 (22.54–31.02)
Female	2.15 (1.88–2.47)	<0.0001	34.66 (30.27–38.50)
Total	2.13 (1.92–2.36)	<0.0001	30.82 (27.86–33.49)
General obesity (BMI ≥ 30 kg/m²)			
Male	1.77 (1.40–2.25)	<0.0001	6.26 (4.09–7.97)
Female	1.75 (1.58–1.94)	<0.0001	12.51 (10.68–14.15)
Total	1.75 (1.57–1.94)	<0.0001	9.28 (7.78–10.54)
Central obesity (Waist circumference ≥ 90 cm)			
Male	2.21 (1.86–2.63)	<0.0001	27.09 (22.84–30.67)
Female	2.16 (1.90–2.46)	<0.0001	26.62 (23.51–29.39)
Total	2.17 (1.98–2.38)	<0.0001	26.71 (24.52–28.71)
Abbreviation: PAF, population attributable fraction.			

other hand, our figures often fall below the prevalence rates observed in Arab communities [23]. Available reports of DM prevalence among Middle Eastern countries vary substantially, ranging from 2.8% in Israel [24] to 29% in Bahrain [25]. In a 2009 systematic review, a prevalence rate of 10.5% (95% CI: 8.6, 12.7%) in the region was recorded [26].

4.2. Trends of diabetes and impaired fasting glucose

Previous reports on the nation-wide prevalence of DM in the adult population have indicated a crude prevalence rate of 7.7% (95% CI: 7.5, 7.9%) and 8.7% (95% CI: 7.4, 10.2%) for 2005 and 2007, respectively [3,16]. Age-adjusted estimates indicate that the prevalence of DM has risen by 35% during 2005–2011; this corresponds to a 5% annual increase. Along the same lines, the crude prevalence of DM among American individuals aged ≥20 years rose from 5.1% in 1988–1994 to 7.7% in 2005–2006, and this trend was significant even after age and sex standardization [19]. A similar increasing trend has also been observed in the UK where a 4.9% annual increase in DM prevalence during a 10-year period (1996–2005) was noted [5]. On the other hand, no substantial changes in IFG prevalence have been documented during 2005–2011 among Iranians; these results are congruent with changes observed in the US between 1988–1994 and 2005–2006 [19].

Although population growth and aging are important contributors to the increase in DM prevalence, evidence indicates that DM prevalence is rapidly increasing within a fixed age stratum, as well [27]. Growing urbanization, employing a westernized diet rich in simple carbohydrates and saturated fats, along with sedentary behaviors and low levels of physical activity, all contribute to this growth among the Iranian adult population [28,29].

4.3. Awareness of diabetes and impaired fasting glucose

Our findings revealed that using FPG, 23.86% of the total population affected by DM is in fact unaware of their disease status. This rate has almost halved in the past seven years, indicating an upsurge in disease self-awareness in the country. Our figure is substantially lower than the observed rate of 40% among US adults with DM (assessed using a
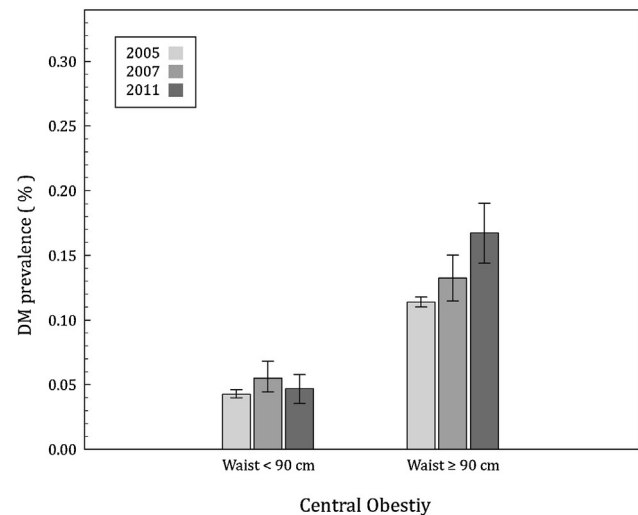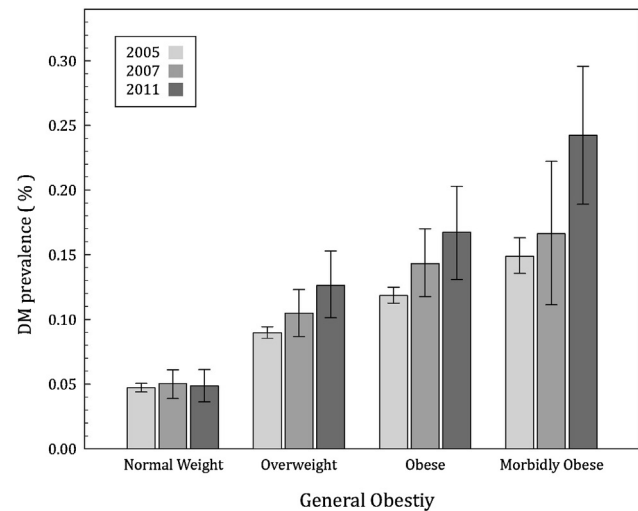
Fig. 1 – Prevalence of diabetes among Iranian adult population across categories of general and central obesity (2005–2011). *Top panel*: Diabetes prevalence in categories of general obesity defined using BMI. Normal weight [OR for trend (95% CI): 1.01 (0.96–1.05), *p* = 0.779]; overweight [OR for trend (95% CI): 1.05 (1.01–1.10), *p* = 0.017]; obese [OR for trend (95% CI): 1.06 (1.01–1.11), *p* = 0.024]; morbidly obese [OR for trend (95% CI): 1.12 (0.06–1.17), *p* < 0.001]. *Bottom panel*: Diabetes prevalence in categories of central obesity defined using waist circumference. Waist < 90 cm [OR for trend (95% CI): 1.00 (0.96–1.05), *p* = 0.873]; waist ≥ 90 cm [OR for trend (95% CI): 1.07 (1.04–1.11), *p* < 0.001]

combination of FPG and 2-hour glucose test) [19]. The proportion of undiagnosed DM is higher among younger age categories (29% in 25–34 years vs. 17% in 65–70 years); although a significant increasing trend with respect to DM diagnosis awareness is also evident. In the absence of a timely diagnosis and apt management, 473,000 Iranian adults currently unaware of their disease, will probably face major DM-related problems in the coming decades.

4.4. Prevalence and trends of diabetes according to age, sex and area of residence

In the 2011 survey, DM and IFG prevalence increased linearly with advancing age; subjects in the 65–70 years category were nine times more likely to have DM than the youngest age group. Indeed, this is the first national survey to include elderly individuals aged 65–70 years, shedding light on the magnitude of the burden associated with caring for the aging population with DM. In the face of increased life expectancy and the graying of the population seen in the past two decades in Iran, a large proportion of elderly individuals with DM will continue to live with the disease. In 2001, 19.7% of US Medicare beneficiaries aged ≥67 years had DM with newly diagnosed cases increasing by 36.9% from 1994 [30]. Age-specific trend analysis also yielded similar results. While adults aged between 25 and 34 experienced an increment of 6.2% in DM prevalence, the rate was substantially higher in older adults (45% and 41.2% for the 45–54 and 55–64 strata, respectively).

It appears that, in Iran, as in the US [19], DM is more common among women, while men are more likely to have IFG. Reports from Turkey and some Arab countries indicate both IFG and DM are more prevalent among women [20,22]. Wild et al., in a pooled analysis of 191 countries worldwide concluded that although DM prevalence is higher in men, there are currently more women living with DM [31]. Iranian adults living in urban areas compared to those in rural regions are 1.7 times more likely to have DM. During the 2005–2011 period, DM growth has also accelerated at higher rates among urban dwellers. These findings are in accord with the notion that glucose intolerance is usually more prevalent in the urban areas of countries facing economic transition [32].

4.5. Contribution of general and central obesity to diabetes prevalence and trends

A plethora of previous studies indicate that obesity is associated with an increased risk of developing type 2 DM [33–35]. PAF is a tangible epidemiologic tool for determining the contribution of any measurable risk factor to a disease of known prevalence. Given the established causal relationship between obesity and diabetes [16,36], PAF is especially suitable for elucidating the extent of the contribution that modifiable risk factors contribute to DM prevalence, aiding policy placements regarding health care resource allocation. Among the Iranian adult population, 9.3% of diabetes cases could be prevented if individuals achieved a goal of BMI < 30 kg/m^2. More drastic decrements in DM prevalence (as high as 30.8%) would occur if the BMI for all adults decreased below 25 kg/m^2.

Recent reports have suggested that around 60% of DM prevalence is attributable to BMI values above normal limits and this contribution further intensifies in BMI values ≥22.5 kg/m^2 [37,38].

Central obesity (defined as a waist circumference ≥90 cm) was associated with a PAF of 27.1% (95% CI: 22.8, 30.7) in men and 26.6% (95% CI: 23.5, 29.4) in women. It is worth mentioning that the calculated PAF for central obesity was roughly three times higher than that of general obesity, suggesting that programs focusing on waist circumference reduction might prove more beneficial compared with weight reduction plans that set goals using BMI. In the present study, the cut-off of 90 cm for waist circumference was chosen because we have previously shown that this is the optimal threshold for diagnosis of metabolic syndrome components among Iranian adults [17]. Using a similar method, the cut-off for BMI has been established at around 25 kg/m^2 in men, and 27.3 kg/m^2 in women [39]. If these cut-off values are to be used instead, the estimated PAF for both indices would become comparable (data not shown).

In the present report, we observed a significant increase in DM prevalence across BMI categories from 4.8% (95% CI: 3.59, 6.13) in normal weight subjects to 24.2% (95% CI: 18.9, 29.6) in morbidly obese individuals. Additionally, the DM growth rate was substantially higher among the morbidly obese subpopulation when compared to lean individuals; a similar pattern was identifiable for central obesity as well. These findings add to the existing literature regarding the detrimental role that obesity plays in the emergence of insulin resistance and highlights the need for emergent interventions targeted at a national level.

4.6. Limitations and future directions

A number of issues in the present study deserve mention. First, although sampling scheme in 2005 and 2007 surveys were fairly similar, a different sampling technique was employed in the 2011 survey, thereby affecting the comparability of the data over time. It is noteworthy however; both statistical methods are robust in the sense that they reliably represent the national population of the country. Second, since 2010, an additional criterion of HbA1c ≥6.5% has been endorsed by the ADA for the diagnosis of DM [40]. It is currently believed that because of greater convenience, less preanlytical variability, and also less day-by-day fluctuations, HbA1c might be superior to FPG (and oral glucose tolerance test) for DM diagnosis [41]. On the other hand, defined cut-off value for HbA1c is ethnic/race dependent, needs proper standardization prior to widespread use, and is relatively costly [41]. For these reasons, in the present study, HbA1c testing was not feasible; thereby diagnosing IFG and DM solely on the basis of the FPG criterion. If HbA1c had been used, the proportion of individuals with DM would have probably increased. Further studies are needed to delineate the appropriate HbA1c cut-off points for the adult population of Iran, using a universally standardized assay.

5. Conclusion

In conclusion, the Iranian adult population with DM has increased by one million in the past seven years. Preventive plans focusing on the control of modifiable risk factors including, but not limited to obesity, need to be put in place in order to curtail the DM epidemic.

Conflict of interest statement

The authors declare no conflict of interest.

REFERENCES

[1] International Diabetes Federation. IDF diabetes atlas. Brussels: International Diabetes Federation; 2011.

[2] Guariguata L. By the numbers: new estimates from the IDF Diabetes Atlas Update for 2012. Diabetes Res Clin Pract 2012;98:524–5.

[3] Esteghamati A, Meysamie A, Khalilzadeh O, Rashidi A, Haghazali M, Asgari F, et al. Third national Surveillance of Risk Factors of Non-Communicable Diseases (SuRFNCD-2007) in Iran: methods and results on prevalence of diabetes, hypertension, obesity, central obesity, and dyslipidemia. BMC Public Health 2009;9:167.

[4] Wang Y, Mi J, Shan XY, Wang QJ, Ge KY. Is China facing an obesity epidemic and the consequences? The trends in obesity and chronic disease in China. Int J Obes 2007;31:177–88.

[5] Gonzalez EL, Johansson S, Wallander MA, Rodriguez LA. Trends in the prevalence and incidence of diabetes in the UK: 1996–2005. J Epidemiol Community Health 2009;63: 332–6.

[6] Lipscombe LL, Hux JE. Trends in diabetes prevalence, incidence, and mortality in Ontario, Canada 1995–2005: a population-based study. Lancet 2007;369:750–6.

[7] American Diabetes Association. Economic costs of diabetes in the U.S. in 2007. Diabetes Care 2008;31:596–615.

[8] Esteghamati A, Khalilzadeh O, Anvari M, Meysamie A, Abbasi M, Forouzanfar M, et al. The economic costs of diabetes: a population-based study in Tehran, Iran. Diabetologia 2009;52:1520–7.

[9] Shaw J, Sicree R, Zimmet P. Global estimates of the prevalence of diabetes for 2010 and 2030. Diabetes Res Clin Pract 2010;87:4–14.

[10] Nichols GA, Brown JB. Higher medical care costs accompany impaired fasting glucose. Diabetes Care 2005;28:2223–9.

[11] Nathan DM, Davidson MB, DeFronzo RA, Heine RJ, Henry RR, Pratley R, et al. Impaired fasting glucose and impaired glucose tolerance implications for care. Diabetes Care 2007;30:753–9.

[12] Hossain P, Kawar B, El Nahas M. Obesity and diabetes in the developing world—a growing challenge. N Engl J Med 2007;356:213–5.

[13] Esteghamati A, Khalilzadeh O, Mohammad K, Meysamie A, Rashidi A, Kamgar M, et al. Secular trends of obesity in Iran between 1999 and 2007: national surveys of risk factors of non-communicable diseases. Metab Syndr Relat Disord 2010;8:209–13.

[14] Chan JM, Rimm EB, Colditz GA, Stampfer MJ, Willett WC. Obesity, fat distribution, and weight gain as risk factors for clinical diabetes in men. Diabetes Care 1994;17:961–9.

[15] Nagaya T, Yoshida H, Takahashi H, Kawai M. Increases in body mass index, even within non-obese levels, raise the risk for Type 2 diabetes mellitus: a follow-up study in a Japanese population. Diabet Med 2005;22:1107–11.

[16] Esteghamati A, Gouya MM, Abbasi M, Delavari A, Alikhani S, Alaedini F, et al. Prevalence of diabetes and impaired fasting glucose in the adult population of Iran: National Survey of Risk Factors for Non-Communicable Diseases of Iran. Diabetes Care 2008;31:96–8.

[17] Esteghamati A, Ashraf H, Rashidi A, Meysamie A. Waist circumference cut-off points for the diagnosis of metabolic syndrome in Iranian adults. Diabetes Res Clin Pract 2008;82:104–7.

[18] Statistical Centre of Iran. Results of 2011 National Census by Age, Sex, Area of Residence, and Province; 2014, www.amar.org.ir/Default.aspx?tabid=765.

[19] Cowie CC, Rust KF, Ford ES, Eberhardt MS, Byrd-Holt DD, Li C, et al. Full accounting of diabetes and pre-diabetes in the US population in 1988–1994 and 2005–2006. Diabetes Care 2009;32:287–94.

[20] Whiting DR, Guariguata L, Weil C, Shaw J. IDF diabetes atlas: global estimates of the prevalence of diabetes for 2011 and 2030. Diabetes Res Clin Pract 2011;94:311–21.

[21] Shera AS, Jawad F, Maqsood A. Prevalence of diabetes in Pakistan. Diabetes Res Clin Pract 2007;76:219–22.

[22] Satman I, Yilmaz T, Sengul A, Salman S, Salman F, Uygur S, et al. Population-based study of diabetes and risk characteristics in Turkey: results of the Turkish diabetes epidemiology study (TURDEP). Diabetes Care 2002;25: 1551–6.

[23] Ashraf H, Rashidi A, Noshad S, Khalilzadeh O, Esteghamati A. Epidemiology and risk factors of the cardiometabolic syndrome in the Middle East. Expert Rev Cardiovasc Ther 2011;9:309–20.

[24] Chodick G, Heymann AD, Shalev V, Kookia E. The epidemiology of diabetes in a large Israeli HMO. Eur J Epidemiol 2003;18:1143–6.

[25] al-Mahroos F, McKeigue PM. High prevalence of diabetes in Bahrainis. Associations with ethnicity and raised plasma cholesterol. Diabetes Care 1998;21:936–42.

[26] Motlagh B, O'Donnell M, Yusuf S. Prevalence of cardiovascular risk factors in the Middle East: a systematic review. Eur J Cardiovasc Prev Rehabil 2009;16:268–80.

[27] Danaei G, Finucane MM, Lu Y, Singh GM, Cowan MJ, Paciorek CJ, et al. National, regional, and global trends in fasting plasma glucose and diabetes prevalence since 1980: systematic analysis of health examination surveys and epidemiological studies with 370 country-years and 2.7 million participants. Lancet 2011;378:31–40.

[28] Esteghamati A, Khalilzadeh O, Rashidi A, Kamgar M, Meysamie A, Abbasi M. Physical activity in Iran: results of the third national surveillance of risk factors of non-communicable diseases (SuRFNCD-2007). J Phys Act Health 2011;8:27–35.

[29] Ghassemi H, Harrison G, Mohammad K. An accelerated nutrition transition in Iran. Public Health Nutr 2002;5: 149–55.

[30] McBean AM, Li S, Gilbertson DT, Collins AJ. Differences in diabetes prevalence, incidence, and mortality among the elderly of four racial/ethnic groups: Whites, Blacks, Hispanics, and Asians. Diabetes Care 2004;27:2317–24.

[31] Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes estimates for the year 2000 and projections for 2030. Diabetes Care 2004;27:1047–53.

[32] King H, Rewers M. Global estimates for prevalence of diabetes mellitus and impaired glucose tolerance in adults. WHO Ad Hoc Diabetes Reporting Group. Diabetes Care 1993;16:157–77.

[33] Ford ES, Williamson DF, Liu S. Weight change and diabetes incidence: findings from a national cohort of US adults. Am J Epidemiol 1997;146:214–22.

[34] Hu G, Lindstrom J, Valle TT, Eriksson JG, Jousilahti P, Silventoinen K, et al. Physical activity, body mass index, and risk of type 2 diabetes in patients with normal or impaired glucose regulation. Arch Intern Med 2004;164:892.

[35] Knowler WC, Barrett-Connor E, Fowler SE, Hamman RF, Lachin JM, Walker EA, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med 2002;346:393–403.

[36] Narayan KMV, Boyle JP, Thompson TJ, Gregg EW, Williamson DF. Effect of BMI on lifetime risk for diabetes in the US. Diabetes Care 2007;30:1562–6.

[37] Berg C, Rosengren A, Aires N, Lappas G, Torén K, Thelle D, et al. Trends in overweight and obesity from 1985 to 2002 in Göteborg, West Sweden. Int J Obes 2005;29:916–24.

[38] Hart C, Hole D, Lawlor D, Davey Smith G. How many cases of type 2 diabetes mellitus are due to being overweight in middle age? Evidence from the Midspan prospective cohort studies using mention of diabetes mellitus on hospital discharge or death records. Diabet Med 2007;24:73–80.

[39] Zandieh A, Esteghamati A, Morteza A, Noshad S, Khalilzadeh O, Gouya MM, et al. Appropriate BMI cut-off values for identification of metabolic risk factors: third national surveillance of risk factors of non-communicable diseases in Iran (SuRFNCD-2007). Ann Hum Biol 2012;39:484–9.

[40] American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes Care 2010;33(Suppl. 1):S62–9.

[41] American Diabetes Association. Standards of medical care in diabetes – 2013. Diabetes Care 2013;36(Suppl. 1): S11–66.