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Comparison of 5-year Incidence of Type 2 Diabetes in Obese and Non-Obese Adult Population: The YaHs Cohort

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ABSTRACT

Background: Obesity is an important predictor of diabetes. Defining the risk of diabetes among obese subjects is important for preventive health strategies. This study aims to compare the 5-year incidence of diabetes in obese and non-obese adult participants aged 20-70 years in a large population sample of central Iran. **Methods**: In this prospective study, 9964 people aged 20-70 years were selected between 2014 and 2015 using multi-stage cluster sampling from Yazd Greater Area, Iran. Participants with diabetes were excluded and non-diabetic individuals were evaluated for incident diabetes after a five-year follow-up. Logistic regression was used to find the association between obesity and 5-year incidence of diabetes in bivariate, and multivariate adjusted models for age, sex, physical activity, medical history, marital status, smoking, and education. **Results**: Out of the initial 9964 participants, 1383 (14%) were excluded due to prevalence of diabetes. The remaining 8413 (86.0%) participants were re-examined in 2019-2020. After five years of follow up, diabetes occurred in 6.6% (n=556) of the participants. The incidence of diabetes in obese men and women was 10.4% (n=109) and 9.9% (n=264), respectively; however, it was 4.5% (n=143) and 2.8% (n=40) in their non-obese counterparts (P<0.01). After multivariate analysis, obesity was associated with a higher likelihood of diabetes in men (OR=1.77, 95% CI: 1.33-2.35), women (OR=2.23, 95% CI: 1.55-3.21), and overall (OR=1.99, 95%CI: 1.60-2.48). Similar findings were obtained in participants aged under and over 60 years (P<0.05). **Conclusion**: There was a positive association between obesity and 5-year incidence of diabetes in an Iranian adult population. Interventions are required to change lifestyle in the adult population especially in younger participants to prevent obesity and diabetes.

Keywords: *Diabetes; Obesity; Incidence; Cohort study*

Background

The prevalence of obesity is increasing worldwide (De Onis and Blössner, 2000, Mokdad *et al.*, 2000). It is predicted that by 2030, there will be over 2.16 billion overweight and 1.12 billion obese globally (World Health Organization, 2016). The World Health Organization has

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reported that obesity is a global epidemic (World Health Organization, 1997). In addition to causing insulin resistance and impaired glucose tolerance, obesity also leads to metabolic disorders associated with diabetes and consequently, increasing overall morbidity and mortality (Larijani *et al.*, 1995).

The proportion of people with type 2 diabetes mellitus (T2DM) and obesity has increased throughout Asia, and the rate of increase and the prevalence of T2DM have now reached epidemic levels in Asia. The International Diabetes Federation (IDF) estimates that 194 million people were diagnosed with diabetes in 2003 and 333 million by 2025 (Roglic and King, 2000).

According to IDF, 463 million adults aged 20 to 79 years worldwide (9.3% of all adults in this age group) have diabetes, and 79.4% of them live in low- and middle-income countries (Williams *et al.*, 2019). According to a study in India, the incidence of T2DM during 10 years of follow-up (2019) was estimated at 21.9% (Vijayakumar *et al.*, 2019). In addition, in this study, the most important risk factors for T2DM were central obesity and overweight. The findings from other studies show conclusive evidence that the incidence of T2DM and pre-diabetes is rapidly increasing in developing countries (Mirzaei *et al.*, 2020, Vijayakumar *et al.*, 2019).

During the Tehran Lipid and Glucose Study in 2007, after the 3.6-year follow-up, the adjusted odds ratio (OR) for diabetes for overweight and obese people compared to normal-weight people was 1.76 and 3.54, respectively. In addition, the risk attributed to the population was 23.3% and 37.1%, respectively. Also, in this study, the independent role of abdominal obesity in the development of diabetes was proven (Hosseinpanah *et al.*, 2007a). Also, according to a study in Yazd, the incidence of diabetes during a 10-year follow-up was 21.4 per 1,000 people of a population per year. In this study, the incidence of diabetes increased by increasing abdominal obesity and body mass index (BMI) (Namayandeh *et al.*, 2019).

The risk of diabetes in Yazd province is twice the national average. Therefore, the high prevalence of diabetes in Yazd can be a serious problem for the health of the people of this province (Sarebanhassanabadi *et al.*, 2020).

In addition, overweight and obesity affect more than half of the population (64%) in Yazd city, and abdominal obesity also has a high prevalence (Mirzaei *et al.*, 2017). According to a study in 2022, the 10-year cumulative incidence of obesity was 14.8% of total population (20.8% for women and 10.5% for men) (Moghtaderi *et al.*, 2022). Therefore, considering obesity as one of the critical concerns of public health in Yazd city, the present study compared the 5-year incidence of T2DM according to presence or absence of obesity in a representative sample of Yazd Greater Area inhabitants aged 20-70 years.

Materials and Methods

Study population: The Yazd Health Study (YaHs) is a prospective cohort study which was initially established in 2014-2015 and included 9964 adults aged 20-70 years living in Yazd Greater Area, Iran. The participants were selected using cluster random sampling. Initially, 200 clusters were randomly selected based on the participants' residential post codes. Then, each cluster of 50 samples was divided into two equal subgroups of men and women. Each group consists of 10 people (5 men, 5 women) in age groups of 20-29, 30-39, 40-49, 50-59, and 60-69 years, which followed up manually (for 5 years) from the beginning of the study. Participants with diabetes at the baseline, with missing covariates or without follow-up information were excluded from the analyses. Details of the study profile was published elsewhere (Mirzaei *et al.*, 2018).

Measurements: In the first phase (baseline) of the cohort study in 2014-2015, biochemical tests, demographic data, smoking status, physical activity, and socioeconomic status were recorded for each participant, and re-evaluated in 2019-2020. Anthropometric measurements were measured by standard methods. Waist circumference (WC) was measured with a non-stretch tape measure at the point between the lower edge of the last rib and the upper edge of the iliac

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crest to the nearest 0.5 cm. Weight was measured using an Omron BF511 portable digital scale and body analyzer (Omron Inc. Nagoya, Japan) with minimal clothing and without shoes to the nearest 0.1 kg. Participants with a body mass index (BMI) ≥ 30 kg/m^2 and WC (≥102 cm in men and ≥88 cm in women), were considered obese.

Blood glucose was measured using Pars Azmoon kits and a Ciba Corning (Ciba Corp., Basel, Switzerland) auto-analyzer. Diabetes was defined using at least one of the following conditions: 1) fasting blood plasma glucose (FPG) ≥126 mg/dl; 2) glycosylated hemoglobin (HbA_1C) ≥6.5%; 3) two-hour postprandial plasma glucose (2hpp) ≥200 mg/dl, or 4) diagnosed by a physician and taking glucose-lowering drugs (Rossi, 2018).

Smoking history was classified as never, former, and current. Educational level was categorized as primary, diploma, and academic. Physical activity was defined by answering positively to never, exercising 2 or more times per week. Medical history and marital status was self-reported and categorized as (yes/no) and (single /married).

Ethical considerations: This study was approved by the ethics committee of School of Public Health in Shahid Sadoughi University of Medical Sciences with ethics code: IR.SSU.SPH.REC.1400.082. Informed consent was obtained from all participants in the first phase and in the follow-up phase of the study.

Data analysis: statistical analysis was performed using STATA version 14.0 software (Stata Corp LP, College Station, TX, USA) and SPSS v25.0 (IBM, New York). Descriptive results were expressed as a number of participants (percentage) for categorical variables and as average standard deviation for continuous variables. Between groups comparisons were performed using chi-square for categorical variables and student's t-test or analysis of variance for continuous variables. Multivariate analysis regarding the determinants of 5-year incidence of diabetes was performed using logistic regression and the results were expressed as OR and 95% confidence interval (95%CI). Multivariate analysis was adjusted for age continuous), sex, physical activity (categorical), medical history (yes/no), marital status (single/married), smoking history (never, former, current), and education (categorical). Statistical significance was considered $P<0.05$.

Results

Selection and characteristics of the participants:

Of the initial 9964 participants, 8362 (83.9%) were included in the analysis. The selection procedure is displayed in **Figure 1**. The 5-year incidence of diabetes in total population was 6.6% (n=556). Characteristics of 5-year incidence of diabetes in men and women are shown in **Table 1**. There were significant differences in BMI, medical history, marital status, education level, physical activity, and obesity between men and women ($P<0.05$). Characteristics of the 5-year incidence of diabetes in men and women are reported in **Table 2**. Participants with higher BMI and WC had higher risk of diabetes ($P<0.05$).

Five-year incidence of diabetes: The incidence of diabetes according to obesity status overall and stratified by sex is provided in **Table 3**. The 5-year incidence of diabetes in obese men, women, and overall participants was 10.4%, 9.9%, and 10%, respectively.

The association between obesity and the incidence of diabetes by sex is reported in **Table 4**. After adjusting for age, sex, physical activity, medical history, marital status, smoking history, and education level, there was a positive significant association between obesity and increased risk of diabetes in men (OR = 1.77, 95% CI: 1.33-2.35), women (OR = 2.23, 95%CI: 1.55-3.21), and total population (OR = 1.99, 95%CI: 1.60-2.48) compared to the non-obese group. On the other hand, participants with obesity had a higher incidence of diabetes, and this association was further confirmed after multivariate analysis; participants with obesity had a two-fold higher likelihood of developing diabetes compared to their non-obese peers. When stratifying on age, younger (<60 years) participants with obesity tended to present a higher likelihood of developing diabetes compared to older, obese participants (**Table 5**).

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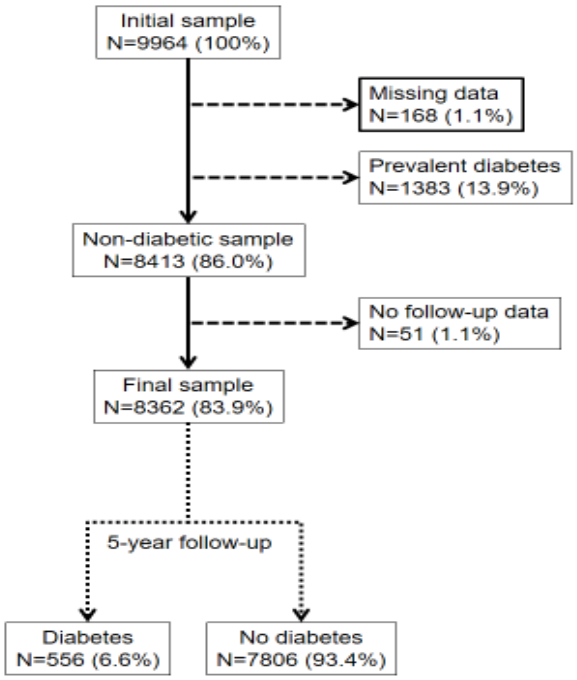

Figure 1. Flow diagram showing the incidence of diabetes in participants of the YaHS: 2015-2020.

Table 1. Characteristics of 5-year incidence of diabetes in men and women, YaHs study, Yazd, Iran

Variables	Incident diabetes		P-value
	Men	Women	
Body mass index (kg/m^2)	28.2±4.5[a]	30.7±5.0	0.01
Waist circumference (cm)	100.5±10.7	100.8±12.5	0.83
Age (year)	49.7±1.13	49.7±1.14	0.94
Smoking history			
Never	183(5.8)[b]	283(7.3)	0.154
Former	14(10.8)	2(12.5)	
Current	51(6.1)	8(9.9)	
Medical history	105(8.1)	126(8.6)	0.01
Education			0.01
Primary	138(7.0)	233(10.5)	
Diploma	69(4.9)	47(3.8)	
Academic	37(4.6)	22(3.4)	
Marital status			0.001
Single	10(1.4)	47(7.9)	
Married	239(6.8)	256(7.3)	
Physical activity			0.008
Never	120(6.9)	173(7.9)	
Once a week	23(5.7)	26(5.9)	
Twice a week	45(6.5)	44(7.0)	
Three to four times a week	21(4.1)	29(7.1)	
Five times a week	38(4.6)	27(6.1)	
Obese			0.01
Yes	109(10.4)	264(9.9)	
No	143(4.5)	40(2.8)	

[a]: Mean±SD; [b]: N (%); using Student t-test for qualitative and Chi-square test for qualitative variables.

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Table 2. Univariate and multivariate regression analysis of the association between body mass index (BMI), waist circumference (WC) and the 5-year risk of diabetes based on age.

	Bivariate	P-value	Multivariate	P-value
<60 years				
BMI<30	1.0 (ref.)	<0.01	1.0 (ref.)	<0.01
BMI≥30	2.81 (2.28-3.45)[a]		2.31 (1.84-2.92)	
≥60 years				
BMI<30	1.0 (ref.)	0.001	1.0 (ref.)	0.004
BMI≥30	1.83 (1.30-2.58)		1.76 (1.19-2.58)	
Men				
<60 years				
WC<88	1.0 (ref.)	<0.01	1.0 (ref.)	<0.01
WC ≥88	2.63 (1.93-3.59)		2.05(1.45-2.88)	
≥60 years				
WC <102	1.0 (ref.)	0.04	1.0 (ref.)	0.11
WC ≥102	1.64 (1.02-2.66)		1.55 (0.91-2.63)	
Women				
<60 years				
WC <102	1.0 (ref.)	<0.01	1.0 (ref.)	<0.01
WC ≥102	3.98 (2.71-5.86)		3.27 (2.14-5.01)	
≥60 years				
WC <102	1.0 (ref.)	0.14	1.0 (ref.)	0.20
WC ≥102	1.73 (0.83-3.60)		1.64 (0.77-3.50)	

[a]: OR (95% confidence interval). Multivariate model was adjusted for sex, physical activity, medical history, marital status, smoking, and education.

Table 3. Five-year incidence of diabetes according to obesity status in men, women, and overall population.

Variables	No diabetes		Incident diabetes		P-value[a]
	N	%	N	%	
Overall					<0.01
Non-obese	4447	57.0	183	32.9	
Obese	3359	43.0	373	67.1	
Men					<0.01
Non-obese	3036	76.3	143	56.7	
Obese	944	23.7	109	43.3	
Women (n)					<0.01
Non-obese	1411	36.9	40	13.2	
Obese	2415	63.1	264	86.8	

[a]: Chi-square test.

Table 4. Bivariate and multivariate analysis of the 5-year incidence of diabetes according to obesity status and sex.

	Bivariate	Multivariate
Overall		
Non-obese	1.0 (ref.)	1.0 (ref.)
Obese	2.70 (2.25-3.24)	1.99 (1.60-2.48)
Men		
Non-obese	1.0 (ref.)	1.0 (ref.)
Obese	2.45 (1.89-3.18)	1.77 (1.33-2.35)
Women		
Non-obese	1.0 (ref.)	1.0 (ref.)
Obese	3.86 (2.75-5.41)	2.23(1.55-3.21)

Multivariate model adjusted for age, physical activity, medical history, marital status, smoking history, and education. For the overall analysis, a further adjustment on sex was conducted.

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Table 5. Bivariate and multivariate analysis of the 5-year incidence of diabetes according to obesity statusand age group.

Variables	Bivariate	Multivariate
<60 years		
Non-obese	1.0 (ref.)	1.0 (ref.)
Obese	2.87 (2.31-3.56)	2.63 (2.04-3.38)
≥60 years		
Non-obese	1.0 (ref.)	1.0 (ref.)
Obese	1.73 (1.22-2.46)	1.57 (1.03-2.39)

Results are expressed as OR and (95% confidence interval). Analysis is conducted using logistic regression. Multivariate model adjusted for age, sex, physical activity, medical history, marital status, smoking history, and education. All results are statistically significant at P-value<0.01.

Discussion

In this prospective study conducted in a representative sample of an Iranian population, the 5-year incidence of diabetes was 6.6%, and there was a strong positive significant association between obesity and 5-year incidence of diabetes.

According to a study in Australia, the incidence of diabetes during an average follow-up of 3.4 years was 1.6%, which was remarkably lower than in the current study (Ding *et al.*, 2015). However, during a 10-year study in India, 21.9% developed diabetes during the follow-up period, which was much higher than in the current study, and which may be partly due to the longer follow-up period (Vijayakumar *et al.*, 2019). Latifi *et al.*, during a 5-year follow-up, reported an incidence of diabetes of 16.8% in Iran (Latifi *et al.*, 2016). Azizi *et al.* during a 3-year follow-up in the Tehran Lipid and Glucose Study reported that 3.7% of people developed diabetes, which is lower than in the current study (HR and Azizi, 2008). Namayandeh *et al.* in 2019, during 10 years, estimated that 21.4 per 1000 of the population-years in Yazd had diabetes among people aged 20–74 years (Namayandeh *et al.*, 2019).

In the current study, the risk of diabetes in obese women was higher than in obese men after a 5-year follow-up. In contrast, according to a prospective study in Tehran (2005) during a 6.3-year follow-up, the incidence of diabetes in both sexes was the same (Azadeh *et al.*, 2005). According to the present study, the risk of developing diabetes in obese men, women, and the total population was 1.77, 2.23, and 1.99 times higher than that of non-obese population. In the study of Hosseinpanah *et al.* (Hosseinpanah *et al.*, 2007b), the OR of T2DM for obese group was 3.61 times higher than the normal-weight group. Another study (Mokdad *et al.*, 2003) reported that the risk of diabetes in adults with both high body fat and severe obesity was 7.37 times higher than in non-obese adults with low body fat. Also, Hart *et al.* stated that there was an association between obesity and increased risk of diabetes (Hart *et al.*, 2007). Additionally, obese participants had the highest risk of developing diabetes compared to non-obese participants in similar studies (Ford *et al.*, 1997, Rhee *et al.*, 2011) and efforts to control weight can play an important role in the clinical management of diabetes (Knowler *et al.*, 2002, Tuomilehto *et al.*, 2001). It has been confirmed that there is a strong relationship between obesity and diabetes (Gautier *et al.*, 2010, Looker *et al.*, 2001, Wannamethee and Shaper, 1999).

According to the findings, there was an association between obesity and increased risk of diabetes in participants aged under and over 60 years. Malone and Hansen (Malone and Hansen, 2019) reported similar results in younger people, i.e. severe obese children and adolescents. Also, according to the study by Farzad Hadayegh *et al.* (Azadeh *et al.*, 2005), general obesity and central obesity, are two indicators predicting the incidence of type 2 diabetes in the Iranian population under 60 years of age.

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There was a positive association between central and abdominal obesity and risk of diabetes. It seems that younger participants who are obese have a higher risk of developing diabetes than older obese people. It would be an important message for public health that the lifestyle of younger people might put them at higher risk of diabetes compared to older people.

The present study is the first study in a large population in the central part of Iran to estimate the incidence of diabetes overall and between obese and non-obese participants. There were some limitations in the present study. The repeated measurement was done after five years; therefore, the exact time of incidence of diabetes is unclear. Also, we could not check the population during the follow up, so lifestyle such as dietary habits, smoking, and physical activity may have changed.

Conclusion

The results of the present study showed the 5-year incidence of diabetes in men, women, and total population in an urban area of central Iran. There was a positive significant association between obesity and 5-year incidence of diabetes in obese participants compared to non-obese participants and younger compared to the elderly. Therefore, changing lifestyle is recommended in relation to obesity and diabetes in the adult population particularly in younger population aged less than 60 years.

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Authors' contributions

Peigan P, Mirzaei M, and Sarebanhassanabadi M designed and organized the study; Sarebanhassanabadi M, Fallahzadeh H, and Peigan P analyzed the data; Peigan P and Sarebanhassanabadi M wrote the manuscript; Sarebanhassanabadi M, Mirzaei M, Marques-Vidal P, and Kraemer A revised the manuscript, critically. All authors read and approved the final manuscript.

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