Diabetes & Metabolic Syndrome: Clinical Research & Reviews 13 (2019) 96–102

Contents lists available at ScienceDirect

Diabetes & Metabolic Syndrome: Clinical Research & Reviews

journal homepage: www.elsevier.com/locate/dsx

Original Article

Diabetes and diabetes care among non-obese South Asian Americans: Findings from a population-based study

Keith Chan [a,*], Leanne R. De Souza [b], Karen Kobayashi [c], Esme Fuller-Thomson [b,d]

[a] School of Social Welfare, University at Albany, SUNY, Albany, NY, USA
[b] Faculties of Social Work & Medicine, University of Toronto, Toronto, ON, Canada
[c] Department of Sociology, University of Victoria, Victoria, BC, Canada
[d] Institute for Life Course and Aging, University of Toronto, Toronto, ON, Canada

ARTICLE INFO

Article history:
Received 23 July 2018
Accepted 21 August 2018

Keywords:
South Asian immigrants
Indian immigrants
BMI
Diabetes mellitus
Obesity
Metabolic disease

ABSTRACT

Aims: The aim of this paper is to provide population-based data from California on: (a) the prevalence and the odds of diabetes among non-obese South Asian (SA) Americans compared to non-Hispanic Whites (NHW); (b) to assess the prevalence and odds of optimal medical care including regular eye exams, foot exams, and the monitoring of hemoglobin A1C blood glucose levels; and (c) To identify the factors that are associated with diabetes among SA Americans.
Methods: The combined 2007, 2009, and 2011 waves of the adult California Health Interview Survey (CHIS) was used to analyze a non-obese (BMI<30) sample of 1251 SA and 72,072 NHW. Chi-square and logistic regression analyses were performed using Stata.
Results: Non-obese SA had more than twice the odds of diabetes in comparison to NHW (OR = 2.50; 1.66, 3.76), even after adjusting for sociodemographic characteristics. Despite their higher propensity for diabetes, there were no significant ethnic differences in the level of optimal care received by those with diabetes. Among non-obese South Asian Americans, the odds of diabetes were higher for older respondents, those without a post-secondary degree, those who were foreign-born, those who had ever smoked, and those with BMI from 25 to 29.99.
Conclusions: Non-obese SA in California experience a disproportionately higher prevalence of diabetes than their NHW counterparts.

1. Introduction

South Asian Americans (SAA) are the fastest growing immigrant group in the United States. SAA includes those with ancestry from India, Sri Lanka, Pakistan, Bhutan, Bangladesh and Maldives [1,2]. Four of five SAA in the United States are originally from India [1,2]. Of the 4.3 million SAA living in the United States [1], the largest proportion of the population reside in California and they represent the fastest growing immigrant group [2]. Our knowledge of the unique health needs of SAA is limited due to both the recency of the population's rapid growth in the USA, and the tendency in most research to combine several ethnic sub-groups, many of which manifest distinct health outcomes [1], into one overarching 'Asian' category. Such collective categorization impedes a clear understanding of SAA ethno-specific propensity for morbidity and the potential for developing an optimized approach to the delivery of preventative healthcare in this large, growing population. Despite the apparent disparities in risk for metabolic morbidity, targeted approaches of care do not exist in this population [1].

Diabetes, in particular, the most common version of the disease, Type 2 Diabetes Mellitus (T2DM), is a growing health concern in South Asian countries such as India, where approximately 62 million citizens have the disease [3]. Indeed, India has the highest disease burden of T2DM among South Asian countries with prevalence rates increasing steadily over the past 40 years [3]. Studies of South Asian immigrant populations in Canada and the United Kingdom, suggest that this group experiences higher risk for metabolic diseases and have a greater susceptibility to heart disease and type 2 diabetes [3].

Existing population studies of the Asian Indian in the United States have reported diabetes prevalence as high as 17.4% [4,5]. This

* Corresponding author. School of Social Welfare, University at Albany, SUNY, School of Social Welfare, University at Albany SUNY, 135 Western Ave, Richardson 277, Albany, NY, 12222, USA.
E-mail address: kchan3@albany.edu (K. Chan).

https://doi.org/10.1016/j.dsx.2018.08.025

extraordinarily high prevalence may be partially attributed to genetic predisposition [6,7] The high prevalence exists despite the substantially lower average age of SA compared to Non-Hispanic Whites (NHW) and the protective behavioural characteristics common to South Asians in the United States and Canada, which include lower prevalence of smoking, lower rates of obesity and high levels of education [8]. Indeed, a large proportion of SA with diabetes are of younger age and experience earlier onset of diabetes than their NHW counterparts [9,10]. SAA are also more vulnerable to diabetes than NHW, even when they are not obese [11]. Therefore, there is a need for research into the unique situation of non-obese SAA.

Our study has the following objectives:

1) To ascertain the prevalence of diabetes in the non-obese SAA and NHW population in California;
2) To determine the odds of diabetes for non-obese SAA vs NHW, after adjusting for well-known risk factors for diabetes;
3) To identify factors associated with diabetes in a sub-sample of non-obese SAA respondents, and;
4) To assess the prevalence and odds of optimal receipt of three types of diabetes care (regular eye exams, foot exams, monitoring of hemoglobin A1C blood glucose levels) and confidence in managing diabetes among SAA living with diabetes in comparison to NHW living with diabetes.

2. Methods

2.1. Data source

As has been discussed elsewhere [12,13] data were from the combined 2007, 2009, and 2011 waves of the adult California Health Interview Survey (CHIS). Using a multistage sampling design, CHIS collected survey data using random-digit-dialing (RDD) with landline and cellular samples for respondents for a representative sample of Californian adults. Interviews were conducted in five languages: English, Spanish, Chinese (Mandarin and Cantonese dialects), Vietnamese, and Korean.

2.2. Sample

The total combined sample of adult respondents over 18 years old from 2007, 2009, and 2011 waves of the CHIS data included 1362 South Asian Americans and 92,703 non-Hispanic Whites. Approximately 5.5% South Asian Americans and 6.7% of non-Hispanic Whites from the full sample had diabetes. Over eight in 10 of South Asian Americans (83.5%) with diabetes are in the non-obese BMI range (i.e., BMI <30). This contrasted with 51.3% of non-Hispanic Whites with diabetes falling within that same BMI range.

For this paper, the final study sample included 73,323 respondents with BMI less than or equal to 29.99 (hereafter referred to as "non-obese"), of whom 1251 were South Asian Americans and 72,072 were non-Hispanic Whites.

2.3. Measures

2.3.1. Identification of individuals with BMI <30

Individuals were asked in the CHIS survey, "How tall are you without shoes?" to determine height, and "How much do you weigh without shoes?" to determine weight. BMI was then calculated by dividing self-reported weight in kilograms by the square of self-reported height in meters.

2.3.2. Identification of individuals with diabetes

The question regarding diabetes was found in the CHIS survey, "Other than during pregnancy, has a doctor ever told you that you have diabetes or sugar diabetes?"

2.3.3. Demographic characteristics

The following demographic variables were examined: 1) South Asian Americans vs. non-Hispanic White ethnicity; 2) sex; 3) age (18 and over); 4) attainment of post-secondary degree; 5) poverty (0–99% of Federal Poverty Level versus 100% or more) - this variable takes into account household income in the context of household composition; and 6) immigrant status (foreign-born or not).

2.3.4. Identification of health-related behavioural variables

For fruit and vegetable intake, respondents were asked, "During the past month, how many times did you eat fruit? Do not count juices," and "During the past month, how many times did you eat vegetables like green salad, green beans, or potatoes? Do not include fried potatoes." Responses to these two questions were used to calculate daily fruit and vegetable intake. Three categories were created with "0 to 1," "more than 1, less than 5," and "5 or more" servings of fruits or vegetables per day.

For cigarette smoking, respondents were asked "Altogether, have you smoked at least 100 or more cigarettes in your entire lifetime?" (coded never vs ever).

Due to changes in questions between the waves, we created a new variable "moderate physical activity" which was defined as follows: From the 2007 dataset, the variable was constructed from the question "During the last 7 days, did you do any moderate physical activities in your free time for at least 10 min?" From the 2009 and 2011 datasets, we used the question "Sometimes you may walk for fun, relaxation, exercise, or to walk the dog. During the past 7 days, did you walk for at least 10 min for any of these reasons?" (coded yes vs no).

BMI was coded into two categories to control for differences in body weight profiles, as BMI less than 25, and BMI of 25–29.99.

2.3.5. Diabetes health management variables

The following diabetes health management variables were examined: (1) regular eye exams; (2) regular foot exams; (3) regular hemoglobin A1C blood glucose level checks; and (4) confidence in managing diabetes. For regular eye exams, respondents were asked, "When was the last time you had an eye exam in which the pupils were dilated?" Responses of "within the past month," "1–12 months ago, and "1–2 years ago" were coded as optimal eye care, and "more than 2 years" coded as sub-optimal eye care. For regular foot exams, respondents were asked, "About how many times in the last 12 months has a doctor checked your feet for any sores or irritations?" Responses of 1–52 were coded as optimal foot exam, and 0 coded as sub-optimal. For regular hemoglobin A1C blood glucose checks, respondents were asked, "About how many times in the last 12 months has a doctor or other health professional checked you for hemoglobin "A one C?" Responses of 2 or more times a year were coded as optimal, and less than 2 times as sub-optimal. For confidence in managing diabetes, respondents were asked, "How confident are you that you can control and manage your diabetes?" Responses of "very confident" and "somewhat confident" were coded as confident, and "not too confident" and "not at all confident" were coded as not confident. For insulin dependence, respondents were asked, "Are you now taking insulin?" Responses of "yes" were coded as insulin dependent, and "no" coded as not insulin dependent.

2.4. Data analyses

Chi-square analyses were used to compare non-obese South

Asian Americans and non-Hispanic Whites with respect to the prevalence of diabetes (Objective 1a) and a range of sociodemographic characteristics and health behaviours. A multivariate logistic regression analysis of diabetes status was conducted to determine the odds of diabetes for non-obese South Asian Americans in comparison to non-Hispanic Whites from California (Objective 1b).

In the South Asian American subsample, chi-square tests were conducted on those with and without diabetes (Objective 2a). Logistic regression analyses of diabetes status were conducted among non-obese South Asian Americans, which controlled for sociodemographic characteristics and health behaviours (Objective 2b).

Further chi-square tests and logistic regression analyses were conducted for non-obese South Asian Americans and non-Hispanic Whites who have diabetes, with respect to health management behaviours, such as regular eye exams, foot exams, A1C glucose levels and confidence in managing diabetes (Objective 3). This set of analyses controlled for insulin use and socio-demographic characteristics and overweight status.

Survey design weights using jackknife replication techniques were employed in the calculation of percentages, standard errors, and odds ratios (OR) to adjust for the probability of selection. A final household weight and 240 replicate weights were created from the 2007, 2009, and 2011 data, using procedures outlined on the CHIS website [6]. All analyses within this article were performed using Stata 13 (StataCorp, College Station, Texas, USA). All sample sizes are provided in their unweighted form.

3. Results

As shown in Table 1, among Californians aged 18 and over with non-obese BMI, SA respondents, on average, had fewer risk factors for diabetes: they were a decade younger, more likely to have a post-secondary degree, were less likely to have ever smoked and had lower BMI compared to their non-Hispanic White counterparts. Despite this "better" risk profile, the prevalence of diabetes was comparable for South Asian Americans and non-Hispanic Whites (4.9% vs 4.3%).

However, once a range of socio-demographics and health behaviors were taken into account, the adjusted odds ratio (OR) of diabetes was more than double for SA Americans as opposed to non-Hispanic Whites (OR = 2.50, 95% CI: 1.66, 3.76) (see Table 1). Males had 45% higher odds of diabetes in this non obese BMI group (OR = 1.45, 95% CI: 1.27, 1.67). Each decade increase in age was associated with a 69% increase in the odds of diabetes (OR = 1.69, 95% CI: 1.61, 1.77). Those without a college degree had 35% higher odds of diabetes (OR = 1.35, 95% CI: 1.18, 1.54). Living in poverty was associated with a 40% increase in odds of diabetes (OR = 1.40, 95% CI: 1.09, 1.79). Those with a BMI from 25 to 29.99 had more than twice the odds of diabetes, compared to those with a BMI of less than of 25 (OR = 2.10, 95% CI: 1.82, 2.43). Fruit and vegetable consumption, smoking history, and level of physical activity had no statistically significant effect on the odds of diabetes for those with non-obese BMI.

3.1. Risk factors associated with having diabetes

In the bivariate analyses restricted to only non-obese South Asian Americans (see Table 2), five characteristics were associated with a higher prevalence of diabetes: male gender (OR = 4.03, 95% CI: 1.62, 10.01), older age (OR = 2.33 per decade, 95% CI: 1.87, 2.92), ever smoking (OR = 2.25, 95% CI: 1.04, 4.86), foreign-born status

Table 1
Descriptive Variables Characteristic and Odds of Having Diabetes (OR) of non-obese South Asians and White Cohorts from the 2007, 2009 & 2011 CHIS (n = 73,323).

	White (n = 72,072)	South Asian (n = 1251)	p-value		Complete Model OR (95% CI)	p-value
Without Diabetes	95.7%	95.1%	0.42	White (Ref.)	1.00	
With Diabetes	4.3%	4.9%		South Asian	2.50 (1.66, 3.76)	<0.001
Demographics				***Demographics***		
Gender				**Gender**		
Male	47.8%	56.5%	<0.001	Female (Ref.)	1.00	
Female	52.2%	43.5%		Male	1.45 (1.27, 1.67)	<0.001
Age				**Age**		
Mean (95% CI)	48.6 ± 0.2 (48.4–48.8)	37.9 ± 1.2 (36.7–39.1)	<0.0001	**(by Decade)**[a]	1.69 (1.61, 1.77)	<0.001
Socioeconomic Status				***Socioeconomic Status***		
Education				**Education**		
No Post-Secondary Degree	46.9%	20.1%	<0.0001	Post-Secondary Degree (Ref.)	1.00	
Post-Secondary Degree	53.1%	79.9%		No Post-Secondary Degree	1.35 (1.18, 1.54)	<0.001
Poverty Level				**Poverty Level**		
Not In Poverty	93.7%	91.9%	0.138	Not In Poverty (Ref.)	1.00	
In Poverty	6.3%	8.1%		In Poverty	1.40 (1.09, 1.79)	<0.01
Health Variables				***Health Variables***		
Daily Fruit and Vegetable Intake				**Daily Fruit and Vegetable Intake**		
0 or 1	41.5%	43.1%	<0.001	0 or 1	1.25 (0.94, 1.67)	0.119
1 to 4	52.8%	53.5%		1 to 4	1.21 (0.91, 1.63)	0.195
5 or more	5.8%	3.5%		5 or more (Ref.)	1.00	
Lifetime Smoking				**Lifetime Smoking**		
Less than 100 Cigarettes	56.2%	85.5%	<0.001	Less than 100 Cigarettes (Ref.)	1.00	
100 or more Cigarettes	43.8%	14.5%		100 or more Cigarettes	1.13 (0.98, 1.31)	0.103
Foreignness				**Foreignness**		
US-born	90.0%	17.4%	<0.001	US-born (Ref.)	1.00	
Foreign	10.0%	82.6%		Foreign	1.17 (0.89, 1.54)	0.257
Exercise				**Exercise**		
Less than Moderate Exercise	26.9%	28.9%	0.400	Less than Moderate Exercise	1.06 (0.93, 1.21)	0.373
Moderate Exercise	73.1%	71.1%		Moderate Exercise (Ref.)	1.00	
Body Mass Index (BMI)				**Body Mass Index (BMI)**		
BMI< 25 (Ref)	56.4%	67.5%	<0.0001	BMI< 25 (Ref)	1.00	
BMI ≥ 25, <30	43.6%	32.5%		BMI ≥ 25, <30	2.10 (1.82, 2.43)	<0.001

All variables in the table were included in the logistic regression analysis.
[a] Age was divided by 10, and can be interpreted as odds for diabetes by decade.

(OR = 4.89, 95% CI: 2.14, 11.15), and a BMI from 25 to 29.99 compared to a BMI of less than of 25 (OR = 3.23, 95% CI: 1.42, 7.31) (see Table 2). No other variables in the analysis were significantly associated with higher odds of diabetes.

3.2. Prevalence and adjusted odds of diabetes management behaviors

Non-obese South Asian American patients with diabetes were equally likely to report optimal frequency of diabetes health management behaviours when compared with non- Hispanic Whites diabetic patients (See Table 3). Even when controlling for insulin dependence, demographic variables, and overweight status, South Asian Americans were comparable to non- Hispanic Whites in terms of the optimal frequency of key diabetes care received (ie., eye exam, foot exam and A1C checks) (See Table 4).

4. Discussion

The findings indicate that 83.5% of all South Asian Americans with diabetes are not obese, which is a significantly higher percentage than Non-Hispanic Whites with diabetes, of whom only one half are non-obese. When the sample was restricted only to the non-obese, SAA have more than twice the odds of diabetes in comparison to NHW when age and other characteristics are taken into account (OR = 2.50, 95% CI: 1.66, 3.76). Both SAA and NHW with diabetes received comparably high levels of optimal diabetes care (i.e., eye exam, foot exam and A1C checks). When only non-obese South Asian Americans were examined, the odds of diabetes were higher among men, older respondents, those who were foreign-born, those who had ever smoked, and those who were in the overweight (BMI from 25 to 29.99) compared to those in the normal weight category (BMI<25).

4.1. Diabetes prevalence

Although a cross-sectional survey does not allow us to determine why non-obese SAA have more than double the odds of diabetes, there are several possible pathways that warrant further investigation. It is well-known that genetic risk factors predispose South Asians to T2DM and this propensity coupled with environmental and lifestyle risk factors may collectively contribute to disproportionately high rates of dysmetabolism [1]. Specific genetic risk factors for T2DM that appear to be amplified in South Asians include a higher degree of insulin resistance and pancreatic β cell dysfunction [7,14,15]. Studies have indicated that fetal programming in response to a nutritionally deprived environment [16,17] and resulting genetic polymorphisms [18], may result in a trajectory of higher propensity for diabetes later in life. Other research has demonstrated that low birth weight [16], maternal overweight and obesity and family history [18,19,20,21], each contribute to T2DM among South Asian immigrants.

4.2. Health related behaviours

Behavioural and lifestyle markers of South Asian Americans are also worth considering to explain the high odds of diabetes among

Table 2
Descriptive Characteristic and Odds of Having Diabetes (OR) of non-obese South Asian American Adults With (n = 89) and Without Diabetes (n = 1162) (total n = 1251).

	% With Diabetes	p-value	Fully Adjusted Model OR (95% CI)	p-value
Demographics				
Gender				
Male	7.6%	<0.0001	4.03 (1.62, 10.01)	<0.01
Female (Ref.)	1.4%		1.00 (Ref)	
Mean Age (95% CI)[a]				
With Diabetes	56.3 (52.6–60.1)	<0.0001	2.33 (per decade)	<0.001
Without Diabetes	36.9 (35.7–38.1)		(1.87, 2.92)	
			1.00 (Ref)	
Socioeconomic Status				
Education				
No Post-Secondary Degree	3.5%	0.38	0.81 (0.22, 2.95)	0.75
Post-Secondary Degree (Ref.)	5.3%		1.00 (Ref)	
Poverty Level				
Not In Poverty (Ref.)	4.6%	0.25	1.00 (Ref)	
In Poverty	8.3%		2.54 (0.71, 9.10)	0.15
Health Variables				
Daily Fruit and Vegetable Intake				
0 or 1	4.9%	0.99	1.87 (0.09, 38.52)	0.684
1 to 4	5.0%		1.94 (0.11, 35.05)	0.652
5 or more (Ref.)	4.4%		1.00 (Ref)	
Lifetime Smoking				
Less than 100 Cigarettes (Ref.)	3.8%	<0.001	1.00 (Ref)	
100 or more Cigarettes	11.3%		2.25 (1.04, 4.86)	<0.05
Foreign-born				
US-born (Ref.)	0.4%	<0.001	1.00 (Ref)	
Foreign-born	5.9%		4.89 (2.14, 11.15)	<0.001
Exercise				
Less than Moderate Exercise	2.5%	0.06	0.41 (0.16, 1.02)	0.056
Moderate Exercise (Ref.)	5.9%		1.00 (Ref)	
Body Mass Index (BMI)				
BMI< 25 (Ref)	3.0%	<0.001	1.00 (Ref)	
BMI ≥ 25, <30	8.8%		3.23 (1.42, 7.31)	<0.01

All variables in the table were included in the logistic regression analysis.
[a] Age was divided by 10, and can be interpreted as odds of diabetes by decade.
Source: 2007, 2009, 2011 CHIS.

Table 3
Descriptive variables characteristic of non-obese south asian american and non-hispanic white cohorts, insulin dependent and non-dependent.

Variable Name	South Asian American[a] (n = 91)	Non-Hispanic White[a] (n = 4308)	p-value	Not Insulin Dependent (n = 3397)[a]			Insulin Dependent (n = 1002)[a]		
				South Asian American	Non-Hispanic White	p-value	South Asian American	Non-Hispanic White	p-value
Eye Exam Regularly Done	90.3%	85.8%	0.32	89.6%	84.3%	0.29	98.9%	90.2%	<0.05
Foot Exam Regularly Done	69.1%	71.4%	0.73	66.9%	68.3%	0.85	96.0%	80.4%	0.07
A1C Checked Regularly Done	75.4%	65.0%	0.17	75.3%	61.6%	0.10	76.2%	74.9%	0.93
Confident to Control & Manage Diabetes[a]	91.8%	94.8%	0.67	91.2%	94.6%	0.65	100.0%	95.4%	0.68

[a] The sample size for this question was different from optimal eye exam, optimal foot exam, and optimal A1C check. For South Asian Americans, the n was 64, and for Non-Hispanic Whites, the n was 2723. For Not Insulin Dependent, the n was 2,152, and for Insulin Dependent, the n was 63.

SAA in comparison to NHW. SAA in this study had lower fruit and vegetable consumption than the non-obese NHW group. However, it should be noted that non-obese SAA (BMI<30) had several protective factors in comparison to non-obese NHW, particularly the decade younger average age and the fact that SAA were less likely to have ever smoked and were more likely to be in the normal weight category than in the overweight category of BMI. In South Asia and India in particular, T2DM prevalence is markedly higher in urban regions than in rural areas [6]. Urban migration is known to be associated with higher sedentary lifestyles and reduced physical activity [1]. Similar to urban-dwelling Americans, those living in urban areas of India, tend to adopt a western diet, high in animal fats and sugar [17,22]. Our findings indicate that in California, SAA have lower levels of physical activity compared to their NHW peers.

4.3. Demographic characteristics

Our analyses indicate that SAA men had higher odds of diabetes compared with women. This is in keeping with the literature that indicates that men have a higher physiological tendency to central adiposity, insulin resistance and metabolic syndrome [23,24], all of which may be exacerbated by high risk lifestyle factors such as increased cigarette smoking and alcohol consumption [25]. However, men in the SAA sample had four times the odds of diabetes compared to women, which is much higher than has been found in the general population. For example, in the larger sample (see Table 1), which had 98% NHW, men had a significant but only modestly higher odds of diabetes compared to women (OR = 1.45; 95% CI = 1.27, 1.67). Further research is needed to determine why SAA men are particularly vulnerable.

It is important not to discount the experiences of SAA women, even though they have a markedly lower prevalence of diabetes in comparison to SAA men. The literature on gestational diabetes mellitus (GDM), suggests that women of Asian and South Asian descent are at increased risk of developing GDM compared with Caucasians, despite lower BMI. It is well established that women who develop gestational diabetes have a 70% increased risk of developing T2DM in the years following pregnancy, thereby contributing to the disease burden of those living with T2DM [26]. While there is limited research on insulin action during pregnancy in this ethnic group, Asian and South Asian ethnicity are both independently associated with increased insulin resistance in late pregnancy [26,27]. In a cross-sectional study of pregnant women stratified for ethnicity, pre-pregnancy BMI had a much greater effect on insulin resistance in pregnancy in Asian women than in Caucasian women; the authors concluded that ethnicity is a factor that modulates the effect of obesity on insulin resistance in pregnancy [27]. There is therefore a need to address metabolic risk early with South Asian immigrant women, including those of child bearing age, as the state of pregnancy itself perpetuates T2DM across generations.

In our cohort, SAA were 10 years younger than Caucasians, while demonstrating a comparable prevalence of diabetes. A recent review examining several high risk attributes of South Asians highlights their vulnerability for T2DM; the review underscored the observed early onset of T2DM in South Asians compared to other ethnic groups, citing a national survey conducted in India that noted that the onset of diabetes occurred before age 50 in 54.1% of cases [9,28,29]. The authors went on to contrast their findings with study results from the United States where only 37.6% of diabetes cases occurred before age 50. Even in the context of a free and universal healthcare system, a longitudinal study of diabetes incidence in Canada reported that the median age at diagnosis was lowest among South Asians (49 years), followed by Chinese (55 years), Blacks (57 years), and Whites (58 years) [20].

Table 4
Logistic Regression of Diabetes Management Variables for Non-Hispanic White vs. South Asian American Adults with BMI <30.

	Crude OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
a. **Optimal Eye Care (n = 4399)**				
White	0.65 (0.28, 1.52)	0.59 (0.25, 1.39)	0.57 (0.24, 1.39)	0.57 (0.23, 1.37)
South Asian	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
b. **Optimal Foot Care (n = 4399)**				
White	1.11 (0.59, 2.10)	1.00 (0.53, 1.89)	1.04 (0.56, 1.95)	1.02 (0.55, 1.93)
South Asian	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
c. **Optimal Testing for A1C Blood Levels (n = 4576)**				
White	0.61 (0.30, 1.24)	0.55 (0.27, 1.12)	0.64 (0.29, 1.41)	0.63 (0.29, 1.40)
South Asian	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
d. **Confidence to Control and Manage Diabetes (n = 2787)**				
White	1.63 (0.38, 70.47)	1.58 (0.04, 68.33)	1.18 (0.02, 58.14)	1.20 (0.02, 59.86)
South Asian	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)

*p < 0.05, **p < 0.01, ***p < 0.001.
Crude includes ethnicity only in the analysis, Model 1 includes Ethnicity and Insulin Dependence, Model 2 includes Ethnicity, Insulin Dependence, Age, Sex, Education, Poverty, and Model 3 includes Ethnicity, Insulin Dependence, Age, Sex, Education, Poverty and Overweight (BMI 25 to 29.99) vs BMI<25.

4.4. Biological factors

Metabolic disturbances that relate to BMI in the natural history of T2DM are embedded in the adipose tissue pathophysiology and metabolism [30]. In the United States, studies have shown that regardless of BMI classification, SA have the highest BMI-specific prevalence of T2DM among all ethnic groups, as high as 17.4%, markedly exceeding T2DM prevalence in NHW (7.8%) [5]. We had restricted our sample to those with non-obese BMI, yet we found that SA in the study were much less likely to be in the overweight category (e.g., BMI between 25 and 30) than in the normal weight category (BMI<25) compared to their NHW counterparts.

A large body of research demonstrates that South Asians have lower rates of obesity as defined by BMI compared to other ethnic groups [3]; however, in recent years growing evidence indicates that this group has a propensity for central obesity as indicated by higher waist-to-hip ratio, higher total overall body fat [31], as well as the diabetogenic abdominal fat including visceral fat and hepatic fat accumulation [3,24,32,33]. Even at a lower BMI, compared to other ethnic groups and Caucasians, South Asians demonstrate higher plasma insulin levels, increased insulin resistance, significantly lower glucose disposal, and higher prevalence of T2DM [3,32,34], and this applies to men, women, adolescents and children, despite lower birth weight [35,36]. Moreover, recent studies have shown that among nondiabetic South Asians, greater visceral fat is associated with increased insulin resistance [11]. The apparent genetic predisposition is partly attributed to epigenetic changes in fetal programming and gene expression, resulting from undernutrition related stressors during intrauterine development [37], consistent with the thrifty genotype hypothesis [38].

South Asia has the highest prevalence of low birthweight worldwide, with India accounting for nearly 40% of global low-birth-weight infants [28]. Maternal undernutrition during pregnancy is purported as a known cause of low birth weight [39], which in turn affects offspring, who experience a high prevalence of overweight, obesity, and central obesity as young adults [40]. The fact that more than four in every five SAA in the California sample had been born abroad underlines the importance of considering prenatal and early life risk factors in their country of origin as a contributor to the increased odds of diabetes in this population.

Not surprisingly, health disparities in South Asians with T2DM extends to other related comorbidities, with higher rates of cardiovascular disease, cerebrovascular disease, peripheral arterial disease and diabetic retinopathy [1]. Screening for diabetes and related morbidities that precede the frank manifestation of T2DM is imperative for disease prevention in all South Asian immigrant populations.

4.5. Health management

We found that despite their higher odds of diabetes, SAA with diabetes in California had better access to care and management of their illness compared to NHW with diabetes. It is possible that the high level of education that most SAA have leads to their self-selection to access appropriate preventive care once they have been diagnosed with diabetes.

There are several limitations to this study which are important to consider. Due to the secondary nature of the data, we had to rely upon self-reports of a medical diagnosis of diabetes rather than blood work or chart reviews. Furthermore, we did not have information on birth weight, age of onset of diabetes, percent body fat, waist circumference, visceral fat, family history of diabetes, nuanced nutritional information and detailed assessment of physical activity.

Despite these limitations, this study provides population-based data on a growing but under-studied population, non-obese SAA. The findings of this study highlight that more than 80% of SAA with diabetes are not obese. Even among the non-obese, relatively young SAA Americans have more than double the odds of diabetes in comparison to NHW, highlighting the need for universal screening for diabetes on a regular basis. Particularly vulnerable SAA adults include men, older respondents, those who are foreign-born, and those who have ever smoked, suggesting the need for targeted outreach to these populations. On a more optimistic note, it appears that for SAA diagnosed with diabetes, the levels of optimal diabetes management (i.e., eye exam, foot exam and A1C checks) are very high and comparable to the NHW group with diabetes.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.dsx.2018.08.025.

References

[1] Gujral UP, Pradeepa R, Weber MB, Narayan KM, Mohan V. Type 2 diabetes in south asians: similarities and differences with white caucasian and other populations. Ann N Y Acad Sci 2013;1281:51–63.

[2] A demographic snapshot of south asians in the United States. 2015. http://saalt.org/wp-content/uploads/2016/01/Demographic-Snapshot-updated_Dec-2015.pdf.

[3] Mohan V, Sandeep S, Deepa R, Shah B, Varghese C. Epidemiology of type 2 diabetes: indian scenario. Indian J Med Res 2007;125(3):217–30.

[4] Misra A, Khurana L. Obesity-related non-communicable diseases: south asians vs white caucasians. Int J Obes 2011;35(2):167–87.

[5] Misra A, Ramchandran A, Jayawardena R, Shrivastava U, Snehalatha C. Diabetes in south asians. Diabet Med 2014;31(10):1153–62.

[6] Mohan V, Deepa R, Velmurugan K, Premalatha G. Association of C-reactive protein with body fat, diabetes and coronary artery disease in asian indians: the Chennai urban rural epidemiology study (CURES-6). Diabet Med 2005;22(7):863–70.

[7] Kooner JS, Saleheen D, Sim X, et al. Genome-wide association study in individuals of south asian ancestry identifies six new type 2 diabetes susceptibility loci. Nat Genet 2011;43(10):984–9.

[8] Shrivastava U, Misra A. Need for ethnic-specific guidelines for prevention, diagnosis, and management of type 2 diabetes in south asians. Diabetes Technol Therapeut 2015;17(6):435–9.

[9] Qiao Q, Hu G, Tuomilehto J, et al. Age- and sex-specific prevalence of diabetes and impaired glucose regulation in 11 asian cohorts. Diabetes Care 2003;26(6):1770–80.

[10] Gupta LS, Wu CC, Young S, Perlman SE. Prevalence of diabetes in New York city, 2002-2008: comparing foreign-born south asians and other asians with U.S.-born whites, blacks, and hispanics. Diabetes Care 2011;34(8):1791–3.

[11] Sandeep S, Gokulakrishnan K, Velmurugan K, Deepa M, Mohan V. Visceral & subcutaneous abdominal fat in relation to insulin resistance & metabolic syndrome in non-diabetic south indians. Indian J Med Res 2010;131:629–35.

[12] Fuller-Thomson E, Roy A, Chan KT, Kobayashi KM. Diabetes among non-obese Filipino americans: findings from a large population-based study. Can J Public Health 2017;108(1):e36–42.

[13] Kobayashi KM, Chan KT, Fuller-Thomson E. Diabetes among asian americans with BMI less than or equal to 23. Diabetes Metab Syndrome 2018;12(2):169–73.

[14] Frayling TM, Timpson NJ, Weedon MN, et al. A common variant in the FTO gene is associated with body mass index and predisposes to childhood and adult obesity. Science 2007;316(5826):889–94.

[15] Yajnik CS, Janipalli CS, Bhaskar S, et al. FTO gene variants are strongly associated with type 2 diabetes in south asian indians. Diabetologia 2009;52(2):247–52.

[16] Pilgaard K, Faerch K, Carstensen B, et al. Low birthweight and premature birth are both associated with type 2 diabetes in a random sample of middle-aged danes. Diabetologia 2010;53(12):2526–30.

[17] Shah M, Vasandani C, Adams-Huet B, Garg A. Comparison of nutrient intakes in south asians with type 2 diabetes mellitus and controls living in the United States. Diabetes Res Clin Pract 2018;138:47–56.

[18] Cho YS, Chen CH, Hu C, et al. Meta-analysis of genome-wide association studies identifies eight new loci for type 2 diabetes in east asians. Nat Genet 2011;44(1):67–72.

[19] Retnakaran R, Connelly PW, Sermer M, Zinman B, Hanley AJ. The impact of family history of diabetes on risk factors for gestational diabetes. Clin Endocrinol (Oxf). 2007;67(5):754–60.

[20] Chiu M, Austin PC, Manuel DG, Shah BR, Tu JV. Deriving ethnic-specific BMI cutoff points for assessing diabetes risk. Diabetes Care 2011;34(8):1741–8.

[21] Kramer CK, Hamilton JK, Ye C, et al. Differential impact of maternal and paternal ethnicity on the pattern of fat distribution in infants at age 3 months.

Pediatr Obes 2016;11(1):11–7.
[22] Shetty PS. Nutrition transition in India. Publ Health Nutr 2002;5(1A):175–82.
[23] Banerji MA, Faridi N, Atluri R, Chaiken RL, Lebovitz HE. Body composition, visceral fat, leptin, and insulin resistance in asian indian men. J Clin Endocrinol Metab 1999;84(1):137–44.
[24] Abate N, Chandalia M, Snell PG, Grundy SM. Adipose tissue metabolites and insulin resistance in nondiabetic asian indian men. J Clin Endocrinol Metab 2004;89(6):2750–5.
[25] Rimm EB, Chan J, Stampfer MJ, Colditz GA, Willett WC. Prospective study of cigarette smoking, alcohol use, and the risk of diabetes in men. BMJ 1995;310(6979):555–9.
[26] Retnakaran R, Hanley AJ, Zinman B. Does hypoadiponectinemia explain the increased risk of diabetes and cardiovascular disease in south asians? Diabetes Care 2006;29(8):1950–4.
[27] Retnakaran R, Hanley AJ, Connelly PW, Sermer M, Zinman B. Ethnicity modifies the effect of obesity on insulin resistance in pregnancy: a comparison of asian, south asian, and caucasian women. J Clin Endocrinol Metab 2006;91(1):93–7.
[28] Ramachandran P. Nutrition and child survival in India. Indian J Pediatr 2010;77(3):301–5.
[29] Ramachandran A, Snehalatha C, Kapur A, et al. High prevalence of diabetes and impaired glucose tolerance in India: national urban diabetes survey. Diabetologia 2001;44(9):1094–101.
[30] Taskinen MR, Boren J. New insights into the pathophysiology of dyslipidemia in type 2 diabetes. Atherosclerosis 2015;239(2):483–95.
[31] Rush EC, Freitas I, Plank LD. Body size, body composition and fat distribution: comparative analysis of european, maori, pacific island and asian indian adults. Br J Nutr 2009;102(4):632–41.
[32] Raji A, Seely EW, Arky RA, Simonson DC. Body fat distribution and insulin resistance in healthy asian indians and caucasians. J Clin Endocrinol Metab 2001;86(11):5366–71.
[33] De Souza LR, Berger H, Retnakaran R, et al. Hepatic fat and abdominal adiposity in early pregnancy together predict impaired glucose homeostasis in mid-pregnancy. Nutr Diabetes 2016;6(9), e229.
[34] Chandalia M, Abate N, Garg A, Stray-Gundersen J, Grundy SM. Relationship between generalized and upper body obesity to insulin resistance in asian indian men. J Clin Endocrinol Metab 1999;84(7):2329–35.
[35] Shah M, Vasandani C, Adams-Huet B, Garg A. Comparison of nutrient intakes in south asians with type 2 diabetes mellitus and controls living in the United States. Diabetes Res Clin Pract 2018;138:47–56.
[36] Al Salmi I, Hoy WE, Kondalsamy-Chennakesavan S, et al. Disorders of glucose regulation in adults and birth weight: results from the australian diabetes, obesity and lifestyle (AUSDIAB) study. Diabetes Care 2008;31(1):159–64.
[37] Chan JC, Malik V, Jia W, et al. Diabetes in asia: epidemiology, risk factors, and pathophysiology. J Am Med Assoc 2009;301(20):2129–40.
[38] Hales CN, Barker DJ. Type 2 (non-insulin-dependent) diabetes mellitus: the thrifty phenotype hypothesis. Diabetologia 1992;35(7):595–601.
[39] Ramakrishnan U. Nutrition and low birth weight: from research to practice. Am J Clin Nutr 2004;79(1):17–21.
[40] Sachdev HS, Fall CH, Osmond C, et al. Anthropometric indicators of body composition in young adults: relation to size at birth and serial measurements of body mass index in childhood in the New Delhi birth cohort. Am J Clin Nutr 2005;82(2):456–66.