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Authors: Talukder, Ashis, Akter, Najiba, and Sazzad Mallick, Taslim

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Exploring Association Between Individuals' Stature and Type 2 Diabetes Status: Propensity Score Analysis

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Ashis Talukder[1], Najiba Akter[2] and Taslim Sazzad Mallick[2]

[1]Statistics Discipline, Khulna University, Khulna, Bangladesh. [2]Department of Statistics, University of Dhaka, Dhaka, Bangladesh.

ABSTRACT: In this article, relationship between respondents' height and occurrence of diabetes has been investigated. This study uses Bangladesh Demographic and Health Survey (BDHS) 2011 data collected from an observational study. Considering height (tall/normal/short) based on percentiles separately for men and women, logistic regression model was fitted to the propensity score (PS)-adjusted weighted data. No significant relationship between respondents' height and diabetes was observed. We also found that the occurrence of diabetes significantly varies with respect to sex, education level, wealth index, body mass index (BMI), and region/division. As, in general, women are shorter than men by nature, we strongly argue that height categories should be defined separately whenever estimation of the effect of height on some response is of interest.

KEYWORDS: blood glucose level, diabetes, inverse probability weighting, propensity score, logistic regression model

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CORRESPONDING AUTHOR: Ashis Talukder, Statistics Discipline, Khulna University, Khulna 9208, Bangladesh. Email: ashistalukder27@yahoo.com

Introduction

Controlling non-communicable diseases (NCDs) is one of the major health and development challenges of the 21st century, particularly in the low- and middle-income countries.[1] The burden of NCDs on social, economic and public health is becoming devastating. Among all deaths due to NCDs, 4% of those are attributable to diabetes.[1] Although this death rate is low as compared with the deaths due to other NCDs, the prevalence of diabetes is increasing globally, particularly in the low- and middle-income countries.[1] In total, 18.8% of the total 382 million patients with diabetes are from South-East Asia (SEA) region, and International Diabetic Federation (IDF) projects about 70% increase in the prevalence in SEA region by 2035.[2] The prevalence of adult diabetes in Bangladesh is 9.4% in 2014.[1]

Although diabetes is not as fatal as other NCDs, it can go unnoticed and undiagnosed for years and increase the risk of developing cardiovascular disease, kidney failure, blindness, and lower-limb amputation. It is alarming that out of 382 million diabetes cases, 46% people are undiagnosed and progressing toward complications unaware.[2] Patients with type 1 diabetes and gestational diabetes (appears during pregnancy) need insulin therapy to survive. Therefore, this 46% undiagnosed patients with diabetes are mainly type 2 diabetic. If the risk factors of type 2 diabetes can be identified and controlled, burden of diabetes as well as other life-threatening diseases caused by diabetes can be reduced.

Recent studies have investigated whether height can be thought of as a potential determinant for the occurrence of diabetes.[3-9] These studies, however, concluded with different contradictory evidences. An inverse association between height and diabetes was found in the literature,[5,7-9] whereas a positive association was reported in Wang et al.[6] However, sex-wise, an inverse association, ie, among women[5] and among men,[10] was also claimed. In contrast, the study in Lorenzo et al[11] could not establish any significant relationship between height and the occurrence of diabetes. These varying conclusions are mainly due to 2 reasons: different data from different geographical areas and use of different statistical models. Because of varying conclusion, the effect of height on diabetes is still a mystery.

Note that most of the above-mentioned findings are based on different observational studies. Drawing conclusion based on any observational study requires careful attention. This is because, unlike experimental study, observational study lacks randomization, and hence, bias naturally arises due to strong association among treatment (such as height) and other covariates while investigating treatment-outcome (such as occurrence of diabetes) association. For example, when association is examined between individuals' height (short/normal/tall) and occurrence of diabetes, a strong association between height and sex puts a question mark about the association observed between height and diabetes. Under observational study design, propensity score (PS) analysis is a useful and widely used tool for finding association between treatment and outcome when association exists among treatment and other background characteristics. This article aims to use PS analysis to investigate the association between height and diabetes and to determine potential determinants of type 2 diabetes.

Methods

Randomized controlled trials (RCTs) are considered to be the ideal setup for estimating treatment effects. However, because of the complexity involved with such a design, observational studies are common in practice, where the experimenter has no control either on the background characteristics or on the random allocation of treatments. Under this setup, subjects choose their own treatments, and the background characteristics of subjects may be different among the treated and untreated groups. Therefore, use of observational studies to estimate causal treatment effect is not feasible unless confounding factors are controlled, at least to some desired level.

A very practical and widely used tool, known as PS, for the adjustment of differences in background characteristics was first proposed in Rosenbaum and Rubin.[12–14] PS is a balancing score, which is in fact the probability of treatment assignment conditional on observed background characteristics. Conditional on the PS, the distribution of observed baseline covariates is similar between treated and untreated subjects. The PS allows one to design and analyze an observational study so that it mimics some of the particular characteristics of an RCT.[15,16]

Four different PS methods are available in the literature: (1) Matching, (2) Stratification, (3) Weighting, and (4) Covariate adjustment.[12,13,15] In this article, we use PS-based weighting to determine the effect of individuals' height on the occurrence of diabetes. This will also allow us to estimate the effects of other factors on the occurrence of diabetes. Although we will be using 3 treatments, ie, 3 height categories, for ease of understanding, we provide an algorithm on PS-based weighting method for 1 treatment case.

Let Y_i be the response, T_i be the indicator variable denoting whether or not ith subject was treated and $Z_i = (z_{i1}, z_{i2}, \ldots, z_{ip})'$ be the set of potential confounders. Furthermore, T_i is significantly associated with Z_i:

1. Fit a binary logit model with response variable, T_i and Z_i as covariates.
2. Estimate the PS, ie, $e_i = \hat{Pr}\left[T_i = 1|Z_i\right]$.
3. For ith subject, calculate the weight, $w_i = (p/e_i)^{T_i}[(1-p)/(1-e_i)]^{(1-T_i)}$, where p is the estimated probability of receiving treatment without considering covariates, ie, $p = \sum_{i=1}^{n}(T_i/n)$.[17,18]
4. Weight the data using w_i and investigate whether association between T_i and Z_i is insignificant. If insignificant, we call balance is achieved.
5. When balance is achieved, that is, treatment groups T_i do not vary with respect to other characteristics Z_i, we then investigate the association between Y_i and T_i using the weighted data. The association is supposed to be true association because T_i is now not associated with other background characteristics.

Note that for multiple treatment setting, instead of binary logit model, a multinomial logit model[19] may be used, and weights may be similarly calculated as in Sicree et al.[3] For details on weighting for multiple treatment case, see the literature.[20,21]

Data and variables

This study considers a secondary data set, namely, Bangladesh Demographic and Health Survey (BDHS) 2011. It is an observational and nationally representative cross-sectional survey conducted by the collaborative effort of the National Institute of Population Research and Training (Bangladesh), ICF international (USA), and Mitra and Associates (Bangladesh). By taking a 2-stage stratified cluster sampling of households, the BDHS 2011 survey got a random sample of total 83 731 household members from 17 141 households. Note that although data from BDHS 2014 are now available, the information on biomarker indices such as systolic blood pressure (SBP), fasting plasma glucose (FPG), and height and weight measurements are only available in BDHS 2011 survey data. In 2011 survey, biomarker information was collected from a subsample of 8835 individuals. There were 3831 women and 3734 men of age 35 years or older those who were participated for FPG measurement.

To determine the true association between diabetes status and stature of individual, we classify our main response variable into 2 categories based on FPG value. If a participant having FPG value greater than 6.1 mmol/L, then he or she will be considered as a diabetic patient,[22] otherwise he or she will be considered as non-diabetic patient. We consider respondents' height as the treatment variable and sex (men and women), education level (no education, primary, secondary, and above secondary), wealth index (poor, middle, and rich) based on percentiles of wealth scores, place of residence (urban and rural), division (Barisal, Chittagong, Dhaka, Khulna, Rajshahi, and Rangpurand Sylhet), body mass index (BMI) category (thin [BMI < 18.5], normal [BMI 18.5-24.9], and overweight [BMI > 24.9])[8] as potential confounders.

Unlike Hoque et al,[8] we consider height with 3 categories. Let p_k be the kth percentile of height. Then, we define

$$Height = \begin{cases} Short, & \text{if } Height < p_{25} = 1.51\text{ m} \\ Normal, & \text{if } p_{25} = 1.51\text{ m} \le Height \le p_{75} = 1.64\text{ m} \\ Tall, & \text{if } Height > p_{75} = 1.64\text{ m} \end{cases}$$

Results

Among the 7565 participants, men and women are almost equal in numbers. It is interesting to see that as education level increases, the percentages of individual decreases. We also found that most of the individuals (67.1%) are from rural area. Dhaka division (17.4%) contains most of the participants, whereas Barisal division (11.4%) contains least participants. More than half of the participants (57.45%) belong to the normal category of BMI. Around 33.3% of participants belong to the each wealth index category because this variable is categorized based on terciles. Moreover, the average height of the participants is noticed to be 1.57 m along with 0.091 m of standard deviation. Respondent's minimum and maximum

Table 1. Adjusted effects of the explanatory variables on the occurrence of diabetes obtained from logistic regression model.

COVARIATES	ODDS RATIO (95% CI)	*P*-VALUE
Height category		
Short	0.897 (0.773, 1.040)	0.150
Normal (ref.)	–	–
Tall	0.822 (0.687, 0.984)	0.033
Education level		
No education (ref.)	–	–
Primary	1.052 (0.905, 1.221)	0.511
Secondary	0.987 (0.823, 1.184)	0.888
Above secondary	1.464 (1.156, 1.853)	0.002
Wealth index		
Poor (< -0.056)	1.111 (0.957, 1.289)	0.167
Middle (–0.056 to 0.023) $(-0.056 - 0.023)$ (ref.)	–	–
Rich (≥ 0.023)	1.255 (1.065, 1.480)	0.007
Place of residence		
Urban (ref.)	–	–
Rural	1.068 (0.928, 1.229)	0.362
Division		
Barisal (ref.)	–	–
Chittagong	0.852 (0.684, 1.061)	0.152
Dhaka	0.524 (0.421, 0.654)	0.000
Khulna	0.427 (0.340, 0.537)	0.000
Rajshahi	0.631 (0.502, 0.793)	0.000
Rangpur	0.494 (0.393, 0.622)	0.000
Sylhet	0.846 (0.672, 1.066)	0.000
BMI		
Thin	1.168 (1.021, 1.337)	0.024
Normal (ref.)	–	–
Overweight	2.101 (1.750, 2.522)	0.000

Abbreviation: CI, confidence interval; ref., reference group; BMI, body mass index.

heights are reported 1.09 and 1.87 m, respectively. Prevalence of diabetes is 33.3%.

We first fit a binary logit model with diabetes status (diabetic/non-diabetic) as response variable and height, education level, wealth index, place of residence, division, and BMI as covariates. The results are displayed in Table 1. It was found that "Tall" individuals have significantly smaller odds of being diabetic as compared with those "Normal" $(P < 0.05)$. We then examine whether height categories are significantly associated with other selected background characteristics which can be treated as potential confounder. The bivariate results between height and other selected characteristics are shown in Supplementary Table 1. It is found that height is significantly associated with all the selected background characteristics. Therefore, the results obtained from Table 1 are not reliable.

Table 2. Assessment of covariate balance for separate cut-off height based weighted data.

COVARIATES	HEIGHT CATEGORY			*P*-VALUE
	SHORT, N (%)	NORMAL, N (%)	TALL, N (%)	
Sex				
Men	910 (25.1)	1813 (50.0)	900 (24.8)	0.986
Women	410 (25.3)	807 (49.8)	402 (24.8)	
Education level				
No education	604 (25.3)	1187 (49.8)	594 (24.9)	0.998
Primary	354 (25.3)	698 (49.8)	349 (24.9)	
Secondary	242 (25.2)	481 (50.2)	236 (24.6)	
Above secondary	119 (24.0)	253 (51.0)	124 (25.0)	
Wealth index				
Poor (< −0.056) (< −0.056)	449 (25.3)	885 (49.8)	443 (24.9)	0.991
Middle (−0.056 to 0.023)(< −0.056– 0.023)	446 (25.4)	872 (49.7)	438 (24.9)	
Rich (≥0.023)	424 (24.8)	862 (50.5)	422 (24.7)	
Place of residence				
Urban	432 (25.3)	849 (49.8)	424 (24.9)	0.979
Rural	888 (25.1)	1771 (50.1)	879 (24.8)	
Division				
Barisal	160 (26.0)	303 (49.2)	153 (24.8)	0.915
Chittagong	200 (25.3)	394 (49.8)	197 (24.9)	
Dhaka	223 (24.9)	451 (50.3)	222 (24.8)	
Khulna	204 (24.7)	417 (50.5)	205 (24.8)	
Rajshahi	176 (25.2)	349 (49.9)	174 (24.9)	
Rangpur	196 (25.3)	386 (49.8)	193 (24.9)	
Sylhet	161 (25.2)	320 (50.1)	158 (24.7)	
BMI				
Thin	413 (25.6)	799 (49.5)	403 (25.0)	0.985
Normal	749 (25.1)	1496 (50.1)	742 (24.8)	
Overweight	157 (24.6)	324 (50.7)	158 (24.7)	

Abbreviation: BMI, body mass index.

Next, we try to balance the data using PS-based weights. To do so, we fit a multinomial logit model with height as response and sex, education level, wealth index, place of residence, division and BMI as covariates and calculate weights, w_i for ith individual. Using the weighted data, we check whether balance is achieved. The balance diagnostic using bivariate analysis is shown in Supplementary Table 2. We found that, although balance is achieved for education level, all other factors are still significantly associated with height. This findings are not surprising at all. From Supplementary Table 1, based on original un-weighted data, we found that only 0.3% women are "tall." As women are naturally shorter than men, in general, defining height categories based on single cut-offs in the combined height (men and women) made the data strongly dependent on sex. With such strong dependence between sex and height, PS-based weighting failed even to balance the data.

We feel that if a relationship between height and diabetes status is of interest, then height categories must be defined separately for men and women. Accordingly, we define height variable in the similar fashion based on percentiles, but

Table 3. Propensity score–adjusted effects of covariates on diabetes status obtained from logistic regression model.

COVARIATES	ODDS RATIO (95% CI)	*P*-VALUE
Height category		
Short	0.917 (0.795, 1.056)	0.229
Normal (ref.)	–	–
Tall	0.877 (0.744, 1.034)	0.119
Sex		
Men (ref.)	–	–
Women	1.133 (0.987, 1.301)	0.075
Education level		
No education (ref.)	–	–
Primary	1.067 (0.918, 1.240)	0.975
Secondary	1.019 (0.848, 1.225)	0.843
Above secondary	1.515 (1.192, 1.924)	0.001
Wealth index		
Poor (< –0.056) (< –0.056)	1.123 (0.967, 1.303)	0.127
Middle (–0.056 to 0.023) (–0.056 – 0.023) (ref.)	–	–
Rich (≥ 0.023)	1.243 (1.050, 1.465)	0.010
Place of residence		
Urban (ref.)	–	–
Rural	1.073 (0.932, 1.235)	0.326
Division		
Barisal (ref.)	–	–
Chittagong	0.839 (0.675, 1.044)	0.115
Dhaka	0.508 (0.408, 0.633)	0.000
Khulna	0.423 (0.337, 0.531)	0.000
Rajshahi	0.625 (0.498, 0.785)	0.000
Rangpur	0.480 (0.382, 0.603)	0.000
Sylhet	0.831 (0.660, 1.046)	0.114
BMI		
Thin	1.202 (1.051, 1.375)	0.007
Normal (ref.)	–	–
Overweight	2.133 (1.773, 2.566)	0.000

Abbreviation: CI, confidence interval; ref., reference group; BMI, body mass index.

separately for men and women. As a result, height is not affected by sex; however, height is still associated with other background characteristic. See Supplementary Table 3 for bivariate results based on separate cut-offs.

We next weight the data using PSs based on separate cut-offs and check whether balance is achieved. The bivariate results under separate cut-offs for the weighted data are shown in Table 2. It is clear that the data are now well balanced, all the selected background characteristics are apparently independent with the new height based on separate cut-offs. As balance is properly achieved, an association between height and occurrence of diabetes may now be investigated.

Result of a logistic regression model for PS-based weighted (separate cut-offs) data is displayed in Table 3. It is observed that height is not significantly associated with the occurrence of diabetes (< –0.056). As the association among height and other potential confounders is controlled through PS-based weighting, this insignificant association between height and diabetes is expected to be the true relationship between them. It is also found that women have about 13% higher odds to become diabetic ($P < 0.10$). Respondents' who have "above secondary" education have 50% higher odds ($P < 0.01$) those who are rich have 24% higher odds (≥ 0.023). This may be due to the fact that educated people tend to belong to "rich" group and their job is usually desk-based. Thus, due to lack of physical activities, they are in risk of diabetes. However, those belonging to Barisal, Chittagong, and Sylhet divisions have similar odds; however, individuals from other divisions have significantly lower odds as compared with Barisal. Further note that, in terms of BMI, those who are not "normal" have higher odds of diabetes. To be specific, this odds is more than double for "overweight" individuals and 20% higher for those who are "thin" ($P > 0.1$).

Discussion and Conclusions

The aim of this study is to inspect the association between individuals' height and occurrence of diabetes. To do so, we use BDHS 2011 data, which is a nationally representative observational study. We are motivated by the fact that there is no clear evidence in the debate of whether height can be thought of as one of the determinants for occurrence of diabetes. We have noticed that earlier researches considered "height" categories based on percentiles of the full sample. We have shown that with such definition of "height" categories, the data become too much imbalanced (Among women, 70% are short and 0.3% are tall), because women are naturally shorter than men, in general. We, therefore, defined "height" in terms of percentiles, but within men and women separately, so that approximately middle 50% are "normal," lower 25% are "short," and upper 25% are "tall," within both men and women. We then conducted a bivariate analysis that showed that although "sex" has no influence on "height" now, height categories still significantly vary with other confounders such as education level or wealth index. To compensate the confounding effect and determine true status of relationship between height and diabetes, we then analyze weighted data, where weights are calculated based on PSs. We did not find any significant relationship between respondents' height and diabetes. However, we found that among women, in high education group, among wealthy people, among those with $\text{BMI} < 18.5$ or $\text{BMI} > 24.9$, the odds of diabetes is higher. The odds of occurrence of diabetes for overweight people are more than twice the odds for "normal" BMI people. We also found that in Dhaka, Khulna, Rajshahi, and Rangpur divisions, the odds are lower as compared with Barisal.

Apart from the ongoing campaigns about the consequences and its prevention of diabetes, special attention should be addressed to the women and to the wealthy people. We have evidence that educated people are wealthier ($P < 0.01$, result is not shown), and generally, wealthier individuals are more involved in desk-work jobs. Thus, targeting this group, implementation of effective motivational seminars regarding the usefulness of maintaining a healthy life style and involvement in physical exercise/activities can reduce the upward trend in the prevalence of diabetes in Bangladesh.

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Author Contributions

AT had the original idea for the study. AT and NA participated in the statistical analysis and helped to draft the manuscript. TSM handled the supervision and prepared the manuscript. All authors read and approved the submitted manuscript.

Availability of Data and Materials

The secondary data sets BDHS, 2011 have been analyzed during the current study are freely available in the following website: http://dhsprogram.com/data/available-datasets.cfm

Supplemental Material

Supplemental material for this article is available online.

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