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Lower Socio-Economic Position Associated With Higher Odds Of Diabetes-Depression Comorbidity

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***Abstract*— Diabetes-depression comorbidity (DDC) adversely affects the quality of life of diabetic patients, complicates the clinical treatment and makes diabetes management very challenging. Therefore, early identification and diagnosis of DDC is crucial to prevent complications and improve the health outcomes among the diabetic patients. This work explores the association between demographic, lifestyle, social economic factors and DDC. The analysis is based on data obtained from the Behavioral Risk Factor Surveillance System (BRFSS), Centers for Disease Control and Prevention (CDC), USA. Logistic Regression was used to explore this association. Women were found to have higher odds of DDC as compared to men [OR 1.30, 95%CI(1.17-1.44), p <0.001]. Additionally, sedentary behaviour and lower socio-economic position was found to be associated with higher odds of DDC. Moreover, a gradient association was observed between socio-economic position (SEP) and DDC. The odds of DDC tend to reduce with improvement in SEP. Our findings underscore the importance of examining and addressing the disproportionate burden of DDC among the lower socio-economic groups.**

***Keywords*— Diabetes, Depression, Comorbidity, Socio-economic position, Logistics Regression, Machine Learning.**

I. Introduction

Diabetes prevalence was projected to reach 366 million by 2030 [1], but by 2014 it had already inflicted 422 million [2, 3]. The rising prevalence and incidence of diabetes is particularly concerning because diabetes severely degrades the overall patient health [4], impairs their quality of daily life [5] and psychological well-being [6]. In fact, diabetics have a 60% [7, 8] higher risk of depression and depressive symptoms [6, 9, 10].

The presence of depression among diabetic patients is formally known as *diabetes-depression comorbidity* (DDC) [11]. DDC escalates the A1c hemoglobin levels [7, 12], mortality [4] and morbidity [10] among diabetic patients. Moreover, it interferes with diabetes treatment [6] and has been found to increase the health care expenditure [9]. Furthermore, the chances of physical disability and later-life functional limitations [13] increase significantly with DDC.

Given the adverse effects of DDC on diabetic patients, it is vital to explore the risk factors associated with it. Such exploration could potentially advance the knowledge about DDC, and facilitate early identification of high-risk groups. Thus, in this work we aim to explore the association of demographic, lifestyle, socio-economic factors with DDC.

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II. Literature Review

Diabetes and depression are often diagnosed together [6, 7]. Longitudinal studies [4, 10, 13, 15, 17] and systematic reviews [2, 9] suggest a causal relationship between diabetes and depression. Some of these identified depression to be risk factor of diabetes [4, 13–15] whereas others [9, 13, 15, 16] found opposite causal link. Nonetheless, the available evidence confirms that *diabetes-depression comorbidity* (DDC) is prevalent to a significant extent.

Previous research has extensively explored the link between DDC and age, gender [4, 6] marital status, education attainment [10, 15], ethnicity [14, 17], and BMI [16, 17]. However, the relationship between socio-economic factors and DDC remains unclear and under-explored. It is vital to study this relationship because poor socio-economic condition because it is significantly related to poor health outcomes among patients in general [18–20]. Moreover, given the challenges associated with DDC management and treatment, it is extremely vital to investigate its relationship with socio economic position (SEP).

Few studies have attempted to explore the association between SEP and DDC, however the indicator designed by them to assess SEP appears to be conceptually week [10, 15, 17]. For instance, [17] estimated participants' SEP by their ability to meet family expense. The authors did not consider parameters such as income [21], education [19], home ownership [22], food affordability [17] and home-rent paying ability [23], which have been demonstrated to affect SEP significantly [18, 19, 23]. We also attempt to address this gap in our work. Finally, given the adverse impact of DDC on diabetic patients and the limited exploration of SEP with DDC, we attempt to examine the relationship between SEP and DDC, adjusting for lifestyle and demographic factors.

III. Methodology

The study is based on pooled survey data obtained from Behavioral Risk Factor Surveillance System (BRFSS) [24]. Survey data for the years 2012 to 2015 were used as these were the years for which the variables required for the study were available. Records with missing values for required variables were excluded.

The choice of independent variable (age, gender, ethnicity, BMI, duration of diabetes, exercise) is based on the evidence of their association with diabetes [6, 10, 19, 23]. Additionally, socio-economic position (SEP) is included as an independent variable because it is related to DDC [19, 21, 23, 25, 26]. For the study, SEP was computed from the BRFSS variables related to income, education, home ownership, food

TABLE I

TABLE REPRESENTING DEFINITION OF THE VARIABLES

Variable	Description
Demography	
Age group (in years)	3=(30,34), 4=(35,39), 5=(40,44), 6=(45,49), 7=(50,54), 8=(55,59), 9=(60,64), 10=(65,69), 11=(70,74), 12=(75,79), 13=80+
Gender	1=Male, 2=Female
Ethnicity	1=White, 2=Black, 3=Hispanic, 4=Other race, 5=Multiracial
Lifestyle	
BMI	17.49 to 46.06
Exercise	1=Yes, 0=No
Diabetes duration (in years)	1=(0,4), 2=(5,9), 3=(10,14), 4=(15,19), 5=(20,24), 6=(25,29), 7=(30,34), 8=(35,39), 9=(40,44), 10=(45,49), 11=(50,54), 12=(55,59)
Socio-economic position	
Education level	1=No school, 2=Grade 1 to 8, 3=Grade 9 to 11, 4=Grade 12, 5=College 1 to 3 years, 6=College 4 years or more
Employment status	1=Employed for wages, 2=Self-employed, 3=Homemaker, 4=Student, 5=Out of work for $<$ 1 year, 6=Out of work for $>$ 1 year, 7=Retired, 8=Unable to work
Income (in American Dollars)	1=($<$10,000), 2=(10,000 to 14,999), 3=(15,000 to 19,999), 4=(20,000 to 24,999), 5=(25,000 to 34,999), 6=(35,000 to 49,999) 7=(50,000 to 79,999), 8=($>$75,000)
Not able to pay rent	1=Always, 2=Usually, 3=Sometimes, 4=Rarely, 5=Never
Scant Meal	1=Always, 2=Usually, 3=Sometimes, 4=Rarely, 5=Never
Home ownership	1=Own, 2=Rent
Diabetes-depression comorbidity	1=Present, 0=Absent

affordability and home-rent paying ability. Based on their values and definitions in the codebook (Table I), SEP formula was defined as shown in Equation (1). For detailed logical explanation of SEP computation please refer to appendix [27]. Note that a higher value of SEP reflects a better socio-economic position. Our intention was to have an indicator which could be used to categorise the respondents into lower, middle, and upper socio-economic position groups. *Duration since diabetes diagnosis* (DSDD) was included as an independent variable because it is found to influence DDC risk [18]. Formula used is shown in Equation (2). Interaction term of SEP and DSDD was also included because we wanted to explore how SEP may modify the association between DSDD and DDC.

$$\textit{Socio-economic position} = \textit{Income} + \textit{Education Level} + \textit{Scant Meal} + \frac{1}{\textit{Home Ownership}} + \frac{1}{\textit{Employment}} + \textit{Rent paying ability} \quad (1)$$

$$\textit{Duration of diabetes} = \textit{Current Age} - \textit{Diabetes Diagnosis Age} \quad (2)$$

The variable Diabetes: *(Ever told) you have diabetes*, and Depression: *For how many days during the past 30 days was your mental health not good?* were used to create the DDC indicator - the dependent variable. DDC was assigned a value of "1" if the respondent had both diabetes and depression (poor mental health days $>= 14$ days) and, a value of "0" if the respondent had diabetes and no depression (poor mental health days < 14 days). The threshold for depression categorisation was set to 14 days in accordance

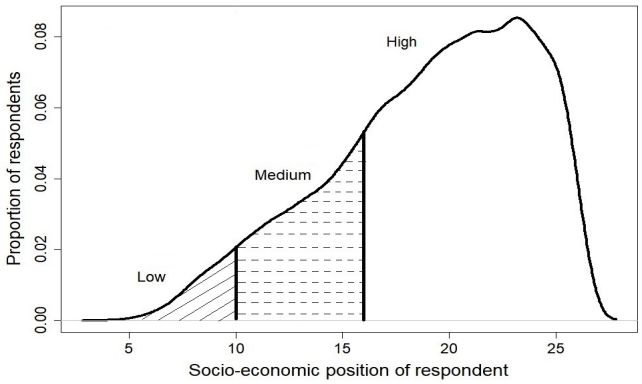

Fig. 1. The figure represents the distribution of socio-economic position of respondents in the dataset. Low, Medium and High socioeconomic categories are specified as shown.

with Diagnostic and Statistical Manual of Mental Disorders (DSM–5) [28]. For the purpose of the study, respondents aged 30 years or above were selected because diabetes prevalence is prominent among them [29]. BMI range was selected as [17.49, 46.06] because beyond this range almost negligible data points remained. Table I describes in details the final set of variables used for the study.

Logistic regression was used to explore the association of lifestyle, demographic factors, socio-economic position with DDC. For this, two models were created, differing in the choice with which SEP was introduced for modelling. In Model I, SEP was considered as a continuous quantitative variable, whereas in Model II, it was considered a categorical variable with three categories: low (SEP$<$ 10), medium (SEP $\in$ [10 16)) and high($>$=16). Category division points were decided based on the assumption that they reasonably capture the low, middle, and high socio-economic position (Fig 1). Two distinct models were created to understand the general and cross-category relationship of SEP with DDC, adjusted for other variables. Note that the interaction between DSDD and SEP was only introduced in Model I. The analysis was done in R version 4.0.3.

IV. Results and Discussion

Initial number of records were 1,873,580. After data cleaning and pre-processing 15,649 remained. Table II provides the descriptive summary of variables in the dataset. 14.14% (N=2212) of respondents were found to have *diabetes-depression comorbidity* (DDC). A higher proportion of DDC was found among women [17.05% (N=1436)] as compared to men [10.74% (N=776)]. The mean age of the respondents was 62.70 [95% CI (62.54-62.87)] years indicating that most respondents were relatively elderly. Mean BMI was 31.03 [95% CI (30.94-31.12)] and median was 30.34 [95% CI (30.34-30.42)] indicating obese respondents on average in the sample. Average *duration since diabetes diagnosis* (DSDD) was 10.41 [95% CI (10.27-10.55)] years. A standard deviation of 8.92 years indicates wide dispersion in DSDD among the respondents.

DDC prevalence among physically active respondents was found to be 10.98% whereas it was 19.46% among sedentary respondents [difference in proportion 8.48%, 95

TABLE II

TABLE REPRESENTING THE DESCRIPTIVE SUMMARY OF RESPONDENTS

Variable	Overall N (%)	DDC N (%)
Total	15649	2212 (14.14%)
Gender		
Male	7225 (46.17%)	776 (10.74%)
Female	8424 (53.83%)	1436 (17.05%)
Ethnicity		
White	10773 (68.84%)	1475 (13.69%)
Black	3145 (20.10%)	451 (14.34%)
Hispanic	732 (4.68%)	120 (16.39%)
Other race	674 (4.31%)	102 (15.13%)
Multiracial	325 (2.08%)	64 (19.69%)
Exercise		
Exercise	9827 (62.80%)	1079 (10.98%)
No Exercise	5822 (37.20%)	1133 (19.46%)
	Mean (95% CI)	Mean (95% CI)
Age (in years)	62.70 (62.54-62.87)	58.78 (58.35-59.22)
BMI	31.03 (30.94-31.12)	32.06 (31.80-32.31)
Duration (in years)	10.41 (10.27-10.55)	10.03 (9.66-10.39)
Socio-economic position	19.10 (19.03-19.17)	15.66 (15.45-15.87)

% CI (0.91-0.93), $p < 0.001$]. This indicates that, sedentary respondents have a higher prevalence of DDC. A variation in DDC prevalence across different ethnicity was observed: White (13.69%, N=1475), Black (14.34%, N=451), Hispanic (16.39%, N=120), Other race (15.13%, N=102) and Multiracial (19.69%, N=64).

Now we discuss the results of modelling. Table III presents the results of Model I. Adjusted for other variables, for every 5 years increase in age, the odds of DDC decrease by 16.9% [OR 0.83, 95% CI (0.81-0.85) $p < 0.001$]. Perhaps with increase in age, people learn to manage complications associated with diabetes [30], including depression [15]. Women have 29.7% [OR 1.30, 95% CI (1.17-1.44), $p < 0.001$] higher DDC odds as compared to men; this may be attributed to higher prevalence of depression among women in general [31].

Ethnic groups of Black [OR 0.64, 95% CI (0.56-0.72), $p < 0.001$] and Hispanic [OR 0.69, 95% CI (0.56-0.86), $p < 0.001$] were found to have lower odds of DDC as compared to White ethnic group. Studies on depression indicate a higher level of prevalence among Black and Hispanic ethnic groups in general [32, 33], but low adherence to treatment and under-reporting depressive behaviour due to socio-cultural factors [34]. This could explain lower odds of DDC among the Black and Hispanic ethnic groups in the dataset. Presence of exercise was found to be associated with lower odds of DDC [OR 0.65, 95% CI (0.59-0.72), $p < 0.001$].

For a unit increase in BMI a marginal 1% [OR 1.01, 95% CI (1.00-1.02), $p < 0.001$] higher odds of DDC was found. This could reflect a more homogeneous distribution of BMI in the sample. For a given *duration since diabetes diagnosis* (DSDD), the DDC risk is modified by the respondent's SEP (Interaction term coefficient: 0.01, $p < 0.01$). The overall coefficient of SEP is thus $(-0.19 + 0.01 * DSDD)$. The value in the bracket is negative for all values of DSDD in the dataset. Thus, it appears that for a given DSDD, poor socio-economic position is associated with higher DDC odds.

In Model II, it was found that people belonging to high

TABLE III

RESULTS OF LOGISTIC REGRESSION FOR MODEL I

Variable	Estimate (95% CI)	p-value
Age	-0.18 (-0.21 to -0.16)	<0.001
Gender[1] (Female/Male)	0.27 (0.17 to 0.37)	<0.001
Ethnicity[2]		
Black	-0.44 (-0.57 to -0.32)	<0.001
Hispanic	-0.36 (-0.58 to -0.14)	<0.01
Other race	-0.05 (-0.29 to 0.18)	0.680
Multiracial	0.12 (-0.18 to 0.42)	0.438
BMI	0.01 (0.00 to 0.02)	<0.05
Exercise (Yes/No)	-0.42 (-0.52 to -0.32)	<0.001
Socio-economic position	-0.19 (-0.21 to -0.17)	<0.001
Duration of diabetes	-0.10 (-0.20 to 0.00)	0.06
Socio-economic position × Duration of diabetes	0.01 (0.00 to 0.01)	<0.01

1 'Male' is used as the reference category.
2 'White' is used as the reference category.

SEP and medium SEP categories have 86.6% [OR 0.13, 95% CI (0.11-0.16), $p < 0.001$] and 57.4% [OR 0.43, 95% CI (0.36-0.51), $p < 0.001$] reduced odds of DDC respectively as compared to those belonging to lower SEP. Results on SEP from Model I and II indicate that a lower SEP is associated with higher odds of DDC, but even within a specific SEP category, lower value of SEP indicates higher DDC risk. A gradient and dose-response relationship seems to exist between SEP and DDC, adjusted for other variables.

From the above results, it is clear that healthcare providers need to be more considerate while treating diabetic patients belonging to lower SEP. Additionally, policymakers must ensure that diabetes care is affordable especially for unprivileged groups. To further reduce DDC risk, mental health surveillance systems could be used for early identification of depression in diabetes patients. In fact, patients suffering from DDC could be provided tele-psychological counselling services [35] to help manage their condition. Thus, digital tools could prove useful to minimise the burden of DDC through personalised and population level health services.

V. CONCLUSION

To our knowledge, this is the first study which explores the association of socio-economic factors with *diabetes-depression comorbidity* (DDC), adjusting for lifestyle and demographic factors. Poor socio-economic position was found to be associated with higher odds of DDC. Moreover, a gradient association was observed between socio-economic position and DDC. Additionally, females, sedentary respondents and obese/morbidly obese respondents were found to have higher odds of DDC. The findings emphasise the need to explore the disproportionate burden of DDC among lower socio-economic groups and identify suitable interventions to minimise the associated complications. Causal link could not be established between socio-economic position and DDC because the study is cross-sectional data analysis. Longitudinal studies could be more useful in this regard.

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