Title:
Estimates and Projections of Prevalence of Type Two Diabetes Mellitus in the US 2001, 2011, 2021: The Role of Demographic Factors in T2DM .

Proposed PAA Session:
410: Obesity, Health and Mortality
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Introduction

Type 2 Diabetes Mellitus (T2DM) is a disease associated with insulin resistance and beta cell dysfunction and is characterized by hyperglycemia and other metabolic abnormalities/or CVD risk factors. Until recent times, onset typically occurred in adulthood. However, there has been a notable increase in T2DM in children and adolescents (Zimmet et al., 2001). T2DM accounts for 90% of all diabetes cases in the United States. Combined, Type 1 diabetes (T1DM) and T2DM comprise the sixth leading cause of mortality and are the leading cause of end-stage renal disease, and non-traumatic lower extremity amputations among all ages and, as well, a leading cause of blindness and cardio vascular disease among people of working age. The American Diabetes Association (ADA) reports that approximately 18.2 million Americans have diabetes mellitus as of 2002 (CDC, 2003).

Changes in the prevalence of T2DM hinge on numerous factors. Several of these factors are reflected in the shifting demographic patterns of the US population. The population is becoming more diversified, with a greater proportion of the population being of minority race, and is older, as the "baby boomers" pass maturity. These two factors have signaled changes in the prevalence of T2DM. In addition, obesity is a major driving force in the diabetes epidemic. Numerous surveys and studies have shown that the US population continues to become more obese.

The goal of this study is to improve the understanding of how changes in the age, gender, racial/ethnic, and BMI characteristics of the US population will affect the number of individuals with T2DM in the United States. Estimating prevalence and evaluating the relative contribution of each factor will thus permit better intervention and treatment efforts for this very costly and debilitating disease:

Research Design and Methods:

Population projections to 2021

We generated our own projections for each the four major ethnic groups of: Hispanics, non Hispanic Whites, non Hispanic Blacks, non Hispanic Others. These were based on results of the midyear 2000 population provided by th US Census Bureau (2003,a). The demographic projections were undertaken using the standard technique of component projection.

The assumptions of population dynamics were based on age-sex-ethnicity-specific fertility, mortality and migration rates, also provided by the Census Bureau (US Census Bureau, 2003,b). There was no need to produce a range of projections, which are usually based on "variants" in fertility levels. Fertility variations would not play a role in these projections – those born in this period will not have time to enter the considered adult ages of 20 and over. Finally, the validity of the projections was checked by comparing the consistency of the sum of the individual race/ethnicity projections with the national set.

Modeling diabetes prevalence and BMI
Data from NHIS 2001 were analyzed to generate diagnosed diabetes prevalence rates for the 2001 model scenario. NHIS, the principal source of information on the health the US residential population, is a multi-purpose health survey conducted by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC. Its data are collected through personal household interviews.

Weighted estimates of diagnosed diabetes prevalence were generated using the adult sample weight. Survey respondents considered to have diagnosed diabetes are those who replied that they had been told by health professionals that they had the disease. Prevalence rates were calculated as a percentage of the weighted total number of individuals within the associated strata.

To model prevalence for future years, we assumed the population prevalence of diabetes was associated with both the demographic profile and the BMI of the population. These scenarios were generated reflecting a 1 to 2 kg/m^2 increase per 10-year period from the average BMI per age/race/gender subgroup seen in the 2001 NHIS results.

Data from NHIS 1998–2001 were utilized to model the association of diagnosed diabetes prevalence with mean population BMI controlling for age, gender, and race. The analysis was limited to these four years of data due to change in diagnostic criteria in 1997 and changing in sampling design.

We fit logistic regression models of the NHIS survey data using the appropriate weights and sample design specifications to correctly estimate the standard errors. The coefficients from these models were used to calculate the odds ratios (ORs) for diabetes prevalence per unit change in BMI. Separate models were fit for each gender. Full-rank models for race, age, and BMI were fit. For both genders, the three-way interaction of race*age*BMI was significant. This indicated that the effect per unit change in BMI was different for the age-by-race groups. As a result, separate coefficients and resulting ORs were generated for each of the 32 models (sixteen age/race groups for each gender). Using the thirty-two age-by-race group models, we predicted the ORs for the scenarios of changes in BMI given earlier. We used 2001 as the baseline to calculate the predicted prevalence of diagnosed diabetes corresponding to a change in the typical BMI The revised prevalence was then applied to the demographic projections for the age/race/gender subgroup for a given year to calculate the estimated absolute number of - diabetes for each subgroup.

Correcting for undiagnosed diabetes
To estimate total prevalence, including the significant proportion of diabetic patients who are undiagnosed, published data on prevalence of undiagnosed diabetes from NHANES 3 (NCHS' National Health Examination Survey) (Harris et al., 1998) and new analyses of NHANES 1999–2000 were utilized for 3 different models. In model 1, we applied the ADA criteria (ADA, 2004) to NHANES 1999-2000. In Model 2, we applied earlier published results for ADA criteria from NHANES 3 (Harris, 1998). It was not possible to evaluate current World Health Organization (WHO) criteria (WHO, 1999). As a result,

for model 3, the earlier WHO criteria were evaluated base on the NHANES 3 results from Harris *et al*, (1998).

Results were then generated for the combined total of diagnosed and undiagnosed individuals within each age/race/gender group for each of the scenarios.

Sensitivity Analysis
Our sensitivity analysis attributes change in diabetes prevalence to the respective factors of population growth, demographic change (in age structure and relative size of ethnic groups) and BMI scenario. Standardization was first undertaken to apply the age/sex/ethnic composition of base population (2001) to the projected populations. Prevalence rates by scenario were applied. Then the sensitivity analysis used a process of elimination. Its primary elements employed the base year population (2001) (a), the standardized population projection for the final year (2021) (b), and the unstandardized population projection for 2021 (c). The difference between these estimates provide 1) the contribution to the diabetic population from the original prevalence level (a), 2) the contribution due to changing demographic composition (b)-(a), and 3) the contribution due to the growth in the population group (c)- (b). Each of these elements is computed for each of the four BMI scenarios.

Selected Results

The four independent component projections (one per racial/ethnic group) were summed and compared to a projection of the United States in its entirety. The variance between the summed groups and the total population differed by no more than 1% in any one age group after 25 years of projection. This is extremely good concordance in the independent projections, requiring no particular need for bi-proportional adjustment. Total results are given in Table 1.

Table 1: Projected population size (2001, 2011, 2021); by ethnicity/race.

Race/ Ethnicity	Age Class	Population 2001	2011	2021	2001-2021 Pct. Increase
Total population	20+	203,076,227	225,418,104	244,630,408	20.5
Whites, Non-Hispanic	20+	146,008,450	152,319,720	155,004,120	6.2
Hispanics	20+	22,436,321	30,583,182	39,589,355	76.5
Blacks, Non-Hispanic	20+	22,478,661	26,430,811	29,916,996	33.1
Others, Non-Hispanic	20+	12,151,008	16,003,246	19,963,412	64.3

Summary results of the number of people with diabetes for 2021 based on demographic projections and four scenarios are presented in Table 2. Diagnosed diabetes and three models of adjustment for are given. Selecting adjustment model 1, the table shows an increase of T2DM of 6 million persons, even with the BMI declining. With BMI changing by 2 kg/m^2 for each 10 year period, the absolute prevalence will double by 2021.

Table 2	2001	2021							
	original	BMI -1		BMI unchanged		BMI +2		BMI +4	
	N	N	%	N	%	N	%	N	%
Total, all races, all ages									
Diagnosed	13,322,745	17,432,745	7.13	18,788,474	7.68	21,852,415	8.94	25,418,777	10.40
Total T2DM:									
Model 1	18,449,080	24,125,246	9.87	26,007,269	10.64	30,261,028	12.38	35,212,940	14.40
Model 2	20,414,284	26,750,754	10.94	28,816,360	11.79	33,483,619	13.70	38,914,623	15.92
Model 3	23,794,423	31,134,883	12.73	33,556,214	13.73	39,028,413	15.96	45,397,936	18.57

Footnotes:

Model 1 – ADA criteria. Diagnosed; undiagnosed ratio derived from NHANES 1999-2000
Model 2 – ADA criteria. Diagnosed; undiagnosed ratio derived from NHANES III
Model 3 – WHO criteria. Diagnosed; undiagnosed ratio derived from NHANES III

There are three principal findings from the sensitivity analysis. With no change in BMI, the influence of population growth and changes in population composition impact the diabetic population growth over the 20-year period equally. Regardless of the BMI change scenario, the absolute contribution from population growth is similar. BMI scenarios work through changes in demographic composition (aging and ethnic composition), such that the contribution due to demographic change to absolute prevalence of diabetes approximately doubles and quadruples in the +2 and +4 BMI scenarios, respectively.

US adult population with T2DM 2001
by BMI change scenario: