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# Comparison of screening scores for diabetes and prediabetes

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ABSTRACT

*Aims:* There are numerous risk or screening scores for the prediction of type-2 diabetes mellitus (DM). In contrast, few scores are available for preDM. In this paper, we compare the two screening scores from the American Diabetes Association (ADA) and Centers for Disease Control and Prevention (CDC) that can be used for DM as well as preDM.

*Methods:* Adult participants ($N = 9391$) without known DM from the National Health and Nutrition Examination Surveys 2009–12 were included. We fitted the factors/items in the ADA and CDC scores in logistic regression with the outcomes of undiagnosed DM, preDM, and combination, and assessed the association and discrimination accuracy. We also evaluated the suggested cutpoints that define high risk individuals. We mimicked the original models/settings but also tested various deviations/modifications often encountered in practice.

*Results:* Both scores performed well and robustly, while the ADA score performed somewhat better (e.g., AUC = 0.77 for ADA and 0.73–0.74 for CDC for DM; 0.72–0.74 and 0.70–0.71 for preDM). The same predictors and scoring rules seem to be reasonably justified with different cutpoints for DM and preDM, which can make usage easier and consistent. Some factors such as race and HDL/LDL cholesterols may be useful additions to health education.

*Conclusions:* Current DM education and screening focus on the prevention and management of DM. The ADA and CDC scores could further help when we identify individuals at high risk for preDM, and teach the importance of preDM during which lifestyle intervention can be effective and urgently needed.



## 1. Introduction

There are a number of prediction or screening scores/models for incident and prevalent type-2-diabetes-mellitus (DM) worldwide (http://www.idf.org/epidemiology/risk-prediction). Some are actively being utilized in clinical and community settings or for research purposes, say, for self-assessment, health education and patient-doctor communication/shared decision making. In contrast, there are few screening scores for preDM, and some may question whether we need scores

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for preDM, different from those for DM. To our knowledge, the two scores from the Centers for Disease Control and Prevention (CDC) and the American Diabetes Association (ADA) that have been developed to help screening DM as well as preDM are relatively well known and easy to use (say, in the pencil-and-paper questionnaire): namely, the 'CDC prediabetes screening test', http://www.cdc.gov/diabetes/prevention/pdf/prediabetestest.pdf and the 'ADA diabetes risk test', http://www.diabetes.org/are-you-at-risk/diabetes-risk-test/. The original models for these scores were developed for the outcome of undiagnosed DM from the National Health and Nutrition Examination Survey (NHANES) 2004 or earlier, by statistical modeling [1,2].

Specifically, the ADA score consists of 7 questions (total score of 0–11) on age, sex, gestational DM, family history of DM, hypertension, physical activity, and obesity (based on body mass index (BMI) via a weight-height chart). The CDC score consists of 7 questions on 6 factors (total score of 0–18) based on age, having delivered a baby weighing more than 9 lb, sibling's DM, parent's DM, physical activity, and obesity; see the scoring algorithms in the Fig. S1. Although the original scores were developed to identify individuals at elevated risk for undiagnosed DM, they were also suggested to be used for undiagnosed preDM, with different cutpoints: $\geqslant$5 for DM and 4 for preDM in the ADA score and $\geqslant$10 for DM and 9 for preDM in the CDC score [1–3]. We also found that some modifications or adaptations are often accompanied to handle realistic issues or improve uptake (e.g., related to data unavailable or limited, less user-friendly questions, varying definitions).

In this paper, we evaluated these two scores in terms of prediction/detection of the outcomes – DM; preDM; and DM and preDM combined, all undiagnosed – and if we can support the use of the same score with different cutpoints for DM and preDM. We also conducted sensitivity and exploratory analyses in order to assess the robustness of the models' performance under various modifications/deviations (e.g., in defining or understanding variables) and restrictions (e.g., on age groups), and the value of additional risk factors commonly considered in relevant contexts. This study may provide some lessons to practitioners, researchers, educators, and users regarding how to wisely use good diabetes and other risk assessment tools in practice.

## 2. Methods

### 2.1. Survey design and participants

We used the NHANES 2009–12, the most recent waves at the time of the study. We restricted our analyses to the adult population, who are $\geqslant$20 years old. We excluded individuals with (1) diagnosed DM (i.e., doctor told you or currently on DM medication) or (2) missing outcomes data (i.e., fasting glucose, A1C, and 2-h plasma glucose by oral glucose tolerance test (OGTT) unmeasured). In the analyses where preDM is the sole outcome, we further excluded those with undiagnosed DM and diagnosed preDM (e.g., doctor told you). Publicly available data were used in our study (http://www.cdc.gov/nchs/nhanes.htm).

### 2.2. Outcomes and predictors

We focused on the variables that are needed in the derivation or use of the two screening scores. We defined predictors and outcomes following the original definitions or the current practice guidelines [4,5] as closely as possible in the primary analyses. Some modifications/adaptations were addressed in the sensitivity/ancillary analyses. To reflect the most common scenario, if data on risk factor is missing, we assigned the score of 0, so we equated the answers of 'No' and 'I don't know'.

The outcomes of type-2 DM and preDM are defined as follows: If a person has fasting glucose $\geqslant$ 7.0 mmol/L, A1C $\geqslant$ 48 mmol/mol, or 2-h glucose $\geqslant$ 11.1 mmol/L, then this person has DM. If a person does not meet the DM criteria, but has 5.6 $\leqslant$ fasting glucose < 7.0, 39 $\leqslant$ A1C < 48, or 7.8 $\leqslant$ 2-h glucose < 11.1, then this person has preDM.

Predictors are defined in the following manner. Age is categorized with the cutpoints of 40, 50 and 60 for the ADA score and of 45 and 65 for the CDC score. Hypertension is defined based on diagnosis (i.e., told by doctor), medication use, or blood pressure (systolic $\geqslant$140 mmHg or diastolic $\geqslant$90 mmHg using the higher value of the first two measurements). Family history of DM is defined based on parent and sibling's DM. [Of note, NHANES we used did not collect family history information separately for parent and sibling so we combined the 2 questions into 1 in the CDC score and assigned the score of 1 in the main analyses. We also assigned the score of 2 and a combination of 1 and 2 in sensitivity analyses.] Pregnancy history data were available so we coded as Yes/No. We created obesity categories as specified in the two scores. The paper version of the both scores provides a small table of weight and height, where the classification corresponds to BMI cutpoints of 25/30/40 for the ADA score (4 groups) and of 27 for the CDC score (2 groups). Finally, there are numerous ways to assess physical activity. The CDC score asks "Get little or no exercise in a typical day?" and the ADA score askes "Are you physically active?" but the same questions were not utilized in the NHANES. Considering these and currently available recommendations from the ADA and CDC (http://www.diabetes.org/are-you-at-risk/lower-your-risk/activity.html and http://www.cdc.gov/diabetes/living/beactive.html), we derived a binary variable by checking if 5 or more days in a typical week of any of the following activities: vigorous or moderate work, recreational work, walk or bicycle.

We described the variables used in sensitivity and ancillary analyses in Appendix. We tried to address frequently encountered situations in a variety of realistic settings where risk scores are used.

### 2.3. Statistical analyses

We combined the NHANES 2009–10 and 2011–12 and accounted for complex survey design in relevant analyses according to the NHANES's analytic guidelines. We repeated some analyses with different weights (e.g., medical exam weight in place of fasting subsample weight) or no weight to include maximum sample/information available, where these 3 different weighting schemes may achieve lowest bias and