Published in final edited form as:

Curr Diab Rep. ; 18(11): 104. doi:10.1007/s11892-018-1090-5.

Building Toward a Population-Based Approach to Diabetes Screening and Prevention for US Adults

Michael E. Bowen^{1,2}, Julie A. Schmittiel³, Jeffrey T. Kullgren^{4,5}, Ronald T. Ackermann^{6,7}, Matthew J. O'Brien^{6,7}

¹Division of General Internal Medicine, University of Texas Southwestern Medical Center, 5323 Harry Hines Blvd., Dallas, TX 75390-9169, USA

²Division of Outcomes and Health Services Research, University of Texas Southwestern Medical Center, Dallas, TX, USA

³Kaiser Permanente Division of Research, Oakland, CA, USA

⁴VA Center for Clinical Management Research, VA Ann Arbor Healthcare System, Ann Arbor, MI, USA

⁵University of Michigan Medical School, Ann Arbor, MI, USA

⁶Division of General Internal Medicine and Geriatrics, Northwestern University Feinberg School of Medicine, Chicago, IL, USA

⁷Northwestern University Institute for Public Health and Medicine, Chicago, IL, USA

Abstract

Purpose of review—Evidence-based treatments for prediabetes can prevent and delay the development of type 2 diabetes in adults. In this review, we propose a framework for population-based diabetes prevention that links screening and prevention activities across key stakeholders. We also discuss gaps in current practice, while highlighting opportunities to improve diabetes screening and prevention efforts population-wide.

Recent findings—Awareness of diabetes risk is low, and many adults with prediabetes are not identified through existing screening efforts. Accumulating evidence and policies support expansion of the Diabetes Prevention Program (DPP) into clinical and community settings. However, the infrastructure to facilitate referrals and promote data exchange among patients, clinical settings, and community-based DPP programs is lacking.

Summary—Development of evidence-driven, scalable processes for assessing diabetes risk, screening eligible adults, and delivering preventive treatments are needed to effectively improve the glycemic health of the US adult population.

Michael E. Bowen michael.bowen@utsouthwestern.edu.

Compliance with Ethical Standards

Conflict of Interest Michael E. Bowen, Julie A. Schmittiel, Ronald T. Ackermann, and Matthew J. O'Brien declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

Keywords

Diabetes risk assessment; Diabetes screening; Diabetes prevention; Population health

Introduction

More than 30 million US adults have type 2 diabetes (T2D), exacting a large public health and economic toll that is steadily increasing as the US population ages [1]. The individual burden of diabetes self-management and treatment is significant, making the prevention or delay of T2D critical for both patients and populations. Recent clinical innovations and interventions have had a large collective impact on the prevalence of complications and life expectancy of patients with diabetes [2]. Part of this success stems from earlier diagnosis and treatment, which appears to have long-lasting effects on the pathophysiology and clinical course of diabetes [3]. In spite of these advances, significant work remains to optimize the glycemic health and health outcomes across the US adult population. Achieving this vision will require coordinated efforts across public health, community, and healthcare settings.

Primary prevention of T2D is critical to curbing the individual, population, and economic toll of T2D. Diabetes risk increases across the glycemic spectrum, making it possible to identify individuals at high risk for diabetes years before they develop clinically apparent T2D. Thus, risk assessment and screening play an important role in curbing the development of T2D. Although clinicians screen for T2D, test results are far more likely to identify individuals with prediabetes, which is a high-risk state for developing T2D. Prediabetes is defined by glycemic markers that are above the normal range but below the diagnostic thresholds for diabetes. In the USA, 86 million adults have prediabetes [1], which confers a 5–10% annual risk and up to a 70% lifetime risk of developing T2D [4, 5, 6••]. Alarming, 90% of individuals with prediabetes are unaware of their diagnosis highlighting an urgent need for scalable risk assessment and screening strategies [7].

Intensive lifestyle interventions can delay or prevent diabetes in individuals with prediabetes [8, 9, 10••, 11]. This has been shown in multiple, large clinical trials including the US Diabetes Prevention Program (DPP) which demonstrated a 58% reduction in the incidence of diabetes with a lifestyle intervention focused on weight loss and physical activity [10••]. Long-term follow-up studies of the DPP and similar intensive lifestyle interventions have demonstrated sustained reductions in diabetes incidence, diabetes complications, cardiovascular mortality, and all-cause mortality [12, 13••, 14–16]. Importantly, the DPP lifestyle intervention is cost-effective among those with prediabetes, which supports its role in helping stem the diabetes epidemic across the US population [17]. The same clinical trial also demonstrated that metformin can prevent or delay the onset of diabetes in adults with prediabetes, although to a lesser extent than intensive lifestyle interventions. Long-term studies of metformin have reported durable reductions in the risk of developing diabetes; however, they have not yet shown significant improvements in complication rates or mortality [16].

Preventing diabetes at the population level requires the development of scalable and sustainable approaches to assess diabetes risk, screen those at high risk, and deliver evidence-supported interventions to high-risk individuals. Population-based diabetes prevention also requires policy changes to improve social determinants of health, such as the quality of the food supply, built environment, and transportation systems. Although challenging, systematic implementation of policy changes in these critical areas could have a broad impact and potentially lower diabetes risk across the entire population. Additionally, public health policies that promote health in communities could augment the effects of evidence-based diabetes prevention efforts targeted toward those at high risk. To improve the reach of evidence-based prevention strategies, coordination of diabetes screening and prevention services across clinical practices, health systems, and community organizations is needed.

The purpose of this paper is to review population-based diabetes screening and prevention efforts among US adults to achieve the following objectives: (1) introduce a conceptual framework linking diabetes screening and prevention, (2) highlight examples of these activities conducted at a population level by various stakeholders, and (3) explore gaps in current practice and highlight future directions for improving population-level diabetes screening and prevention.

Population-Based Diabetes Screening and Prevention Framework

Successful population-based diabetes screening and prevention strategies require coordinating activities across different stakeholders in both clinical and community settings. Examples of these stakeholder groups and their potential actions are provided in Table 1. Individuals, health professionals, healthcare systems, health payers, community organizations, and public health agencies are collectively responsible for assessing diabetes risk, ordering screening tests, managing screening test results, and engaging in preventive treatments. We propose a model of population-based diabetes prevention (Fig. 1) that includes each of these care processes and illustrates recommended actions across each domain. We utilize Fig. 1 as an organizing framework for discussing processes of care (i.e., diabetes risk assessment, diabetes screening, and treatment of prediabetes), followed by a discussion of how these processes have been implemented in population health practice by different stakeholders. Diagnosing diabetes represents the final step in our model, after which individuals require evidence-based interventions for diabetes care that are beyond the scope of this review.

Diabetes Risk Assessment: Identifying High-Risk Individuals for Screening

Assessing an individual's risk of diabetes is critical to determining whether or not a screening test is indicated. Risk assessment utilizes epidemiologic risk factors for developing diabetes, including age, minority race/ethnicity, family history of diabetes, physical inactivity, and metabolic conditions such as overweight/obesity, dyslipidemia, hypertension, gestational diabetes, and polycystic ovarian syndrome [19•, 20]. These and other risk factors form the basis for two common risk assessment strategies: diabetes screening guidelines and diabetes risk scores.

Diabetes screening guidelines utilize patient—or clinician—identified risk factors to determine who should receive a screening test. The most common US screening guidelines are the American Diabetes Association (ADA), American Association of Clinical Endocrinologists (AACE)/American College of Endocrinology (ACE), the US Preventive Services Task Force (USPSTF), and the Department of Veterans Affairs and Department of Defense guidelines [19•, 21–23]. These guidelines recommend screening based on a single “test-no test” decision threshold. Differences in how each guideline defines “high risk” substantially impact the number of individuals eligible for screening. Further, the different risk factors included in each screening recommendation produce tradeoffs in their sensitivity and specificity for identifying adults with prediabetes or undiagnosed diabetes [24••]. Diabetes risk scores utilize risk factors to assign a point value based on the presence of risk factors or specific levels of the risk factors (e.g., body mass index). Unlike screening guidelines, risk scores quantify diabetes risk across a range of disease probabilities, allowing users the flexibility to select different testing thresholds depending on the clinical context and their preferences regarding sensitivity and specificity [25]. Table 2 provides examples of existing diabetes risk scores and screening guidelines, including available evidence on the performance characteristics using US population data

Population-Based Application of Diabetes Risk Assessment: Challenges and Limitations

Population-level studies suggest that existing diabetes screening guidelines may identify between 47.3 and 98.3% of US adults with prediabetes or undiagnosed diabetes [24••, 29, 30••]. While numerous risk scores have been developed using US cohorts and population-level data, their uptake has been low [31–35] because some data required for calculation are not commonly available in routine practice (e.g., waist-to-hip ratio) [36•, 37]. Public health agencies and expert groups such as the Centers for Disease Control and Prevention (CDC), American Diabetes Association (ADA), and American Medical Association (AMA) have recently promoted risk scores as part of their public awareness campaigns [38]. The ADA Diabetes Risk Test and the CDC Prediabetes Test are designed for use by individuals in the community or healthcare settings [26, 28]. Those with elevated risk scores are advised to contact their healthcare provider for a diabetes screening test and/or enroll in an evidence-based diabetes prevention program. Although the uptake of these risk scores in community settings is unknown, their use in clinical practice is low [39]. This may, in part, reflect challenges of automating these tools within electronic health records (EHRs) due to risk factors that are not systematically captured in structured data fields (e.g., physical activity) [40].

Current Gaps and Ongoing/Future Work: EHR-Based Risk Assessment

Risk scores designed to use clinical data from the EHR are uncommon. However, the derivation and validation of diabetes risk scores in clinical populations using EHR data represents an opportunity to efficiently scale risk assessment to large populations of patients. EHR-based diabetes risk scores should utilize clinical data that are reliably captured in structured data fields, including laboratory tests such as non-diagnostic random blood glucose (RBG) values < 200 mg/ dL. Although not a recommended screening test, most patients engaged in clinical care have random glucose values available [41,42•]. These values are commonly ignored in clinical practice because the patient’s fasting state is

unknown [43]. However, RBG is useful for diabetes risk assessment and case-finding strategies in clinical practice [24••, 44••, 45] to identify high-risk individuals in need for gold-standard glycemic screening tests [46]. Risk assessment using RBG alone has high sensitivity, specificity, and discrimination (area under receiver operator curve [AROC] 0.88) for detecting undiagnosed diabetes (Table 2) [24••]. For identifying prediabetes or undiagnosed diabetes, a risk score based on RBG, age, race/ethnicity, BMI, and hypertension has good discrimination (AROC 0.75) and performs better than ADA and USPSTF diabetes screening guidelines [46]. Leveraging EHR data and infrastructure can help automate risk assessment in clinical populations, and also prompt outreach to high-risk patients to encourage subsequent diabetes screening tests and interventions to prevent diabetes.

Diabetes Screening and Case-Finding Strategies

Diabetes screening is the process of laboratory testing to determine individuals' glycemic state (i.e., normal, prediabetes, or T2D). Three tests are currently recommended for this purpose: hemoglobin A1c, fasting blood glucose, and oral glucose tolerance tests. Expert consensus recommends that individuals with normal glycemic test results receive repeat screening in 3 years [19•]. It is recommended that those found to have prediabetes based on an abnormal screening result (hemoglobin A1c 5.7–6.4% or fasting blood glucose 100–125 mg/dL or 2-h oral glucose tolerance test 140–199 mg/dL) undergo a repeat glycemic test within 12 months and be offered evidence-based treatments for prediabetes [19•]. Current clinical practice guidelines recommend that adults whose screening result falls within the diabetes range (hemoglobin A1c ≥ 6.5% or fasting blood glucose ≥ 126 mg/dL or 2-h oral glucose tolerance test ≥ 200 mg/dL) should have the test repeated to establish a diagnosis of diabetes. Alternatively, a diagnosis of T2D can be made using a single fasting blood sample if both fasting glucose and hemoglobin A1c results are in the diabetes range [19•, 47•]. Performing both tests simultaneously may streamline diagnosis in clinical practice by eliminating the need for a second clinical visit for confirmatory testing.

While widely recommended by expert groups, systematic, population-based screening and treatment of adults at high risk for diabetes has not been shown to reduce mortality in clinical trials when compared to routine screening and treatment in clinical practice [48]. This is in part explained by advances in cardiovascular risk reduction that have significant mortality benefits in individuals with and without diabetes. Given the low risk of testing, high prevalence of diabetes, and high complication rates and associated costs, some may argue that screening all adults seems reasonable. Furthermore, targeted screening may miss an important population of patients who could benefit from risk reduction counseling and prediabetes treatment. However, universal diabetes screening is not recommended given the lack of data demonstrating a mortality benefit [19•, 20, 48]. Using mortality reduction as the “gold standard” to evaluate screening approaches neglects intermediate micro- and macrovascular complications of T2D that adversely impact patients' quality of life and raise mortality risk, while imposing significant healthcare costs.

In the absence of universal screening, diabetes and prediabetes detection depends on case-finding or opportunistic screening, which is the ordering of screening tests when individuals

present to the healthcare system for reasons unrelated to screening [49]. Slightly more than half of all adult patients complete gold-standard diabetes screening tests in clinical practice; however, many high-risk individuals are missed despite having opportunities for screening during healthcare encounters [42•]. Reflex diabetes screening in response to elevated random blood glucose levels may improve case detection. Additional improvements in screening rates may be achieved by coupling diabetes screening with existing clinical workflows for cholesterol screening. This may enhance uptake since cholesterol screening is widely performed in clinical practice. Further research comparing the effectiveness (i.e., diagnostic yield), reach (i.e., test completion), and costs of targeted, opportunistic screening versus “pragmatic” population screening is needed.

Population-Based Application of Diabetes Screening: Challenges and Limitations

Scaling evidence-based diabetes screening and case-finding strategies is critical to diagnosing the 7.2 million US adults with undiagnosed T2D and the 77.4 million US adults with undiagnosed prediabetes [1]. Uptake of screening guidelines is hindered by having multiple recommendations that each include different risk factors. In practice, healthcare providers may find it difficult to make informed decisions about which guideline they should follow, or even remember the corresponding risk factors. These barriers highlight the need for health system interventions to promote widespread adoption of evidence-based diabetes screening guidelines across the clinical populations they serve. Examples may include diabetes screening policies endorsed by health systems that are supported by electronic clinical decision support tools or automated order functionality.

Reimbursement for diabetes screening is critical to supporting and scaling population-level strategies to prevent diabetes. The Affordable Care Act (ACA) requires payers to fully cover USPSTF-recommended preventive services, such as screening guidelines. Although this represents an important step in expanding access to diabetes screening, the 2015 USPSTF guideline narrowly defines risk using age and BMI alone (Table 2). The same guideline suggests that clinicians consider performing a screening test for patients with minority race/ethnicity or other risk factors; however, these indications for screening may not be covered by insurers [21]. Additionally, Medicare does not cover hemoglobin A1c as a diabetes screening test, even though it is considered an eligibility criterion for Medicare to reimburse delivery of the DPP. Expansion of screening guidelines and insurance coverage for screening tests remain opportunities to improve alignment between evidence and practice [21].

Current Gaps and Ongoing/Future Work: New Opportunities for Diabetes Screening

Point-of-care devices (POC) to measure hemoglobin A1c represent a potential opportunity to scale and expand the reach of population-based diabetes screening efforts. These benchtop instruments enable hemoglobin A1c measurement in either community settings or clinics, where they are frequently used for clinical decision-making in patients with known diabetes. There are many POC devices on the market, but concerns about their accuracy and precision have hindered their use for screening. However, recent research suggests that at least two of these POC instruments meet the widely accepted performance criteria established by the National Glycohemoglobin Standardization Program [22, 23]. Some recent evidence suggests that using POC A1c analyzers for diabetes screening in primary care clinics may

increase identification of prediabetes and diabetes compared to usual care [50]. Expansion of POC devices for diabetes screening in dental offices, pharmacies, and community-based settings are promising, but require clear instructions about follow-up procedures and linkage to clinical care for those who require repeat testing or treatment [51, 52]. The endorsement of ambulatory blood pressure measurement in the USPSTF hypertension screening guideline suggests the potential for a similar community-based approach in diabetes screening [53•, 54].

Treatments to Prevent Diabetes

Intensive Lifestyle Interventions—Intensive lifestyle interventions are the most effective treatment to prevent or delay the onset of T2D. The most widely studied of these, the Diabetes Prevention Program (DPP), is a goal-based diet and physical activity intervention that encourages 150 min per week of moderate physical activity and 7% weight loss from baseline. The DPP is most often delivered by lay lifestyle coaches during an in-person, group-based setting over at least 1 year of active intervention. A large number of studies have implemented the DPP in diverse clinical and community-based settings (e.g., YMCAs, churches, nonprofit organizations, employer groups), with meta-analyses demonstrating significant weight loss and associated cardiometabolic improvements [55–58]. There are also studies testing delivery of the DPP via telephone and web-based applications, which have achieved similar outcomes [59–63].

While the DPP has the largest evidence base supporting its effectiveness, other intensive lifestyle programs may also reduce the risk of developing diabetes among high-risk adults. The USPSTF recommends behavioral counseling to promote a healthful diet and physical activity among overweight or obese adults who have other cardiovascular risk factors such as prediabetes [64]. While DPP was cited in this recommendation as an exemplar lifestyle intervention, the USPSTF recommendation is based on a review of many intensive behavioral counseling programs that included at least five contacts over a minimum of nine months [64]. For example, many commercial weight loss programs are similar in intensity to the DPP and rely on evidence-based behavioral strategies utilized in the DPP, such as goal setting, stimulus control, and self-monitoring [65]. One recent study tested the effectiveness of a modified Weight Watchers program for adults with prediabetes and demonstrated a 5.5% weight loss from baseline to 12 months [66]. With their widespread availability and options for digital delivery, commercial weight loss programs offer another promising community-based opportunity to scale diabetes prevention efforts.

Population-Based Delivery of Intensive Lifestyle Interventions

In 2010, Congress authorized the CDC to establish the National Diabetes Prevention Program (NDPP), which supports workforce development and a recognition program for organizations that deliver DPP effectively and with fidelity to the evidence-supported intervention [67]. Initial efforts to develop a national network of DPP delivery sites involved a public-private partnership between CDC, YMCA, and UnitedHealth Group, which scaled DPP programs in YMCAs across 23 US states [68]. There are currently over 1700 programs recognized by the CDC, and the YMCA remains the largest delivery site with more than 200 participating locations [69, 70]. A recent study reported aggregate outcomes from the first 4

years of the NDPP program, which were comparable to those achieved in individual community-based studies of DPP. From 2012 to 2016, the NDPP enrolled 14,747 adults whose mean weight loss was 4.2% from baseline to the completion of the year-long program [71•]. In addition to these national efforts, some US states have also developed DPP programs. For example, the Montana Cardiovascular Disease and Diabetes Prevention Program reported delivering DPP in 16 sites, achieving a mean weight loss of 6.2 kg among almost 4000 participants between 2008 and 2012 [63, 72, 73].

Large health systems have also developed resources to prevent diabetes across the clinical populations they serve. Recently, the Veterans Health Administration (VHA), the nation's largest integrated health system, adapted its MOVE! Weight Management Program for Veterans to incorporate core design features of the DPP (e.g., 16 sessions comprised of a closed group of participants and a consistent facilitator) [74]. MOVE! remains available to all Veterans who are patients of the VHA and want to lose weight, irrespective of whether they have prediabetes. In addition, AllianceChicago, a national network of federally qualified health centers with a shared, centrally hosted EHR platform has developed customized EHR tools to support DPP delivery across its clinics. These EHR tools help (1) identify patients who are eligible to participate, (2) track attendance and weight measurement during sessions, and (3) generate automated reports required by the CDC to maintain NDPP recognition status. Together, these experiences suggest the potential for population-based effectiveness of the DPP, and the feasibility of strategies to broaden its reach within health systems. Medicare reimbursement for DPP, which began in early 2018, may enhance widespread dissemination of DPP by providing a potentially sustainable funding stream to support the program's delivery.

Metformin and Other Medications

Metformin has demonstrated durable efficacy in reducing diabetes risk among adults with prediabetes in clinical trials [13•, 16]. The efficacy of metformin is greatest in patients with the following demographic and clinical characteristics: 45 years old, African American race, prior history of gestational diabetes, body mass index ≥ 35 kg/m², and fasting glucose 110–125 mg/dL [10•]. This evidence suggests that metformin may be a useful adjunct to lifestyle change in at least some patient groups, or an effective stand-alone treatment for those not interested in lifestyle change. However, metformin is underutilized for diabetes prevention in routine care, with prescribing estimates ranging from <0.1 to 3.7% of patients with prediabetes [75, 76•, 77]. Although randomized trials of other antidiabetic medications for diabetes prevention have reported mixed results on diabetes risk reduction, they are not recommended or routinely prescribed to prevent or delay diabetes.

Current Gaps and Ongoing/Future Work: Towards an Integrated Approach

Achieving the goal of population-based diabetes prevention will require a robust referral system linking adults with prediabetes to evidence-supported lifestyle interventions. Not all eligible adults will be able to enroll in NDPP programs because of competing personal demands and limited capacity of current NDPP infrastructure. Adults with elevated diabetes risk who are interested in NDPP programs can refer themselves or receive referrals from their healthcare providers to community-based healthy lifestyle programs following

diagnosis of prediabetes. However, these referral strategies rely on individuals' having knowledge of their glycemic status and local prevention programs, both of which are likely limited. Community-based programs are dynamic, and maintaining up-to-date knowledge of available programs is challenging for community members and healthcare providers alike. Further investment and research on community-based options for patient-centered weight loss, nutrition, and physical activity programs are needed to maximize the treatment of prediabetes [78].

Community-based organizations face multiple challenges in delivering the NDPP. Staff training is coordinated by CDC and a small number of other national partners, who have created a centralized training infrastructure to help maintain fidelity to the evidence-supported intervention. Community organizations are responsible for collecting and reporting the data required to receive and maintain certification through the NDPP recognition program; however, they often have limited expertise, infrastructure, and capacity to support these processes. They also have little or no experience billing Medicare and other payers for services delivered, which may impact the long-term sustainability of programs. Additionally community-based organizations are challenged to identify eligible participants because they lack access to health records, and community members are often unaware of their elevated diabetes risk [7].

These challenges highlight an urgent need for expanded infrastructure and policies to promote data exchange between patients, healthcare settings, and community-based providers while supporting DPP delivery and reimbursement [79]. Development of data sharing agreements and platforms supporting secure data exchange between community programs, health systems, and participants are needed to streamline DPP referrals and reporting of outcomes. Clinical decision support provides one potential strategy to facilitate curation of available prevention programs and automate referrals between clinics, where individuals are identified as having prediabetes, and DPP delivery sites in both clinical and community settings. This EHR-based strategy could also promote prescribing of metformin for treatment of prediabetes. Data linkages between organizations delivering the DPP and the healthcare system are critical for research on the long-term health outcomes and impact of DPP participation. Studies testing the effectiveness of clinical decision support as a clinic-based strategy for adopting treatments to prevent diabetes are currently underway.

Third-party administrators focused on disease prevention are beginning to link patients, payors, and physicians with organizations delivering the DPP, and continued growth in this space is likely to play an important role in expanding the reach of the DPP. Data sharing across compatible platforms could support an expanded role for third-party administrators in coordinating DPP referrals across multiple clinical systems, health departments, employers, community-based organizations, and individuals seeking DPP programs. Further research is needed on the role of advanced payment models to fund community DPP delivery by encouraging payers to enter formal partnerships with health systems and manage the glycemic risk of populations through health promotion and disease prevention.

Our findings in this paper and recommendations for future research should be considered in the context of international efforts in diabetes screening and prevention, employer-based

programs, policy-based programs impacting diabetes prevention at the population level, and management of T2D. These topics have been reviewed elsewhere and complement our current focus on population-based approaches to diabetes screening and prevention in the U.S. [18••, 76••, 80•].

Conclusions

Like most chronic diseases, individuals develop T2D as a result of the complex interaction between biologic and behavioral risk factors. Public health interventions and changes to the built environment are critical to building sustainable efforts to prevent diabetes. Opportunities to target diabetes prevention interventions to high-risk individuals occur when these individuals interface with community and clinical settings. Successful management of glycemic risk within and across populations requires structured processes and coordination of care to deliver risk assessment, screening, and interventions across settings. Coordinated approaches to diabetes prevention may help organize and scale existing efforts that span clinical and community settings.

Until there are effective and sustainable policies to address the burden of diabetes for the entire adult population, prevention efforts should focus on coordinated action across multiple stakeholders and venues to ensure that high-risk individuals are identified, offered appropriate treatment, and followed longitudinally. Future work in this area requires technological infrastructure that operates across these settings to help link eligible individuals with evidence-based lifestyle programs and/or metformin. At the same time, healthcare providers, health systems, payers, and public health agencies have a shared responsibility to support high-risk individuals and facilitate patient-centered decisions about assessing their diabetes risk, undergoing screening, and choosing treatment. Future research will help evaluate and refine these ongoing efforts.

Acknowledgments

Dr. Bowen is supported by NIDDK K23-DK104065 and the Dedman Family Scholars in Clinical Care. Research reported in this publication was supported by the National Institute of Diabetes and Digestive and Kidney Diseases of the National Institutes of Health. Dr. O'Brien is supported by the National Institute of Diabetes and Digestive and Kidney Diseases of the National Institutes of Health (R21-DK112066). The content of this article is solely the responsibility of the authors and does not necessarily reflect the official views of the National Institutes of Health. Dr. Kullgren is a VA HSR&D Career Development awardee at the Ann Arbor VA. He is supported by the Department of Veterans Affairs, Veterans Health Administration, Health Services Research and Development Service. The views expressed in this article are those of the authors and do not necessarily reflect the position or policy of the Department of Veterans Affairs or the United States government.

Jeffrey T. Kullgren has received consulting fees from SeeChange Health and HealthMine, and a speaking honorarium from AbilTo, Inc.

References

Papers of particular interest, published recently, have been highlighted as:

- Of importance
- Of major importance

1. Centers for Disease Control and Prevention. National Diabetes Statistics Report: Estimates and Its Burden in the United States. In: The U.S. Department of Health and Human Services, editor Atlanta, GA 2017.
2. Gregg EW, Li Y, Wang J, Burrows NR, Ali MK, Rolka D, et al. Changes in diabetes-related complications in the United States, 1990–2010. *N Engl J Med*. 2014;370(16):1514–23. 10.1056/NEJMoa1310799. [PubMed: 24738668]
3. Holman RR, Paul SK, Bethel MA, Matthews DR, Neil HAW. 10-year follow-up of intensive glucose control in type 2 diabetes. *N Engl J Med*. 2008;359(15):1577–89. 10.1056/NEJMoa0806470. [PubMed: 18784090]
4. Gerstein HC, Santaguida P, Raina P, Morrison KM, Balion C, Hunt D, et al. Annual incidence and relative risk of diabetes in people with various categories of dysglycemia: a systematic overview and meta-analysis of prospective studies. *Diabetes Res Clin Pract*. 2007;78(3):305–12. [PubMed: 17601626]
5. Nathan DM, Davidson MB, DeFronzo RA, Heine RJ, Henry RR, Pratley R, et al. Impaired fasting glucose and impaired glucose tolerance implications for care. *Diabetes Care*. 2007;30(3):753–9. [PubMed: 17327355]
6. Menke A, Casagrande S, Geiss L, Cowie CC. Prevalence of and Trends in Diabetes Among Adults in the United States, 1988–2012. *JAMA*. 2015;314(10):1021–9. 10.1001/jama.2015.10029. [PubMed: 26348752] ••This study of NHANES data estimates trends in diabetes prevalence among U.S. adults over more than 2 decades.
7. Centers for Disease Control and Prevention. Awareness of prediabetes–United States, 2005–2010. *MMWR Morb Mortal Wkly Rep*. 2013;62(11):209.
8. Pan XR, Li G, Hu YH, Wang JX, Yang WY, An ZX, et al. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance: the Da Qing IGT and diabetes study. *Diabetes Care*. 1997;20(4):537–44. 10.2337/diacare.20A537. [PubMed: 9096977]
9. Tuomilehto J, Lindström J, Eriksson JG, Valle TT, Hämäläinen H, Ilanne-Parikka P, et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. *N Engl J Med*. 2001;344(18):1343–50. 10.1056/NEJM200105033441801. [PubMed: 11333990]
10. Knowler W, Barrett-Connor E, Fowler S, Hamman RF, Lachin J, Walker E, et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *N Engl J Med*. 2002;346(6):393–403. 10.1056/NEJMoa012512. [PubMed: 11832527] ••This seminal clinical trial tested the comparative efficacy of the Diabetes Prevention Program lifestyle intervention vs. metformin vs. placebo in adults with prediabetes, providing most of the data about diabetes prevention in U.S. adults.
11. Ramachandran A, Snehalatha C, Mary S, Mukesh B, Bhaskar A, Vijay V. The Indian diabetes prevention programme shows that lifestyle modification and metformin prevent type 2 diabetes in Asian Indian subjects with impaired glucose tolerance (IDPP-1). *Diabetologia* 2006;49(2):289–97. 10.1007/s00125-005-0097-z. [PubMed: 16391903]
12. Li G, Zhang P, Wang J, Gregg EW, Yang W, Gong Q, et al. The long-term effect of lifestyle interventions to prevent diabetes in the China Da Qing diabetes prevention study: a 20-year follow-up study. *Lancet*. 2008;371(9626):1783–9. 10.1016/S0140-6736(08)60766-7. [PubMed: 18502303]
13. Knowler W, Fowler S, Hamman R, Christophi C, Hoffman H, Brenneman A, et al. 10-year follow-up of diabetes incidence and weight loss in the Diabetes Prevention Program Outcomes Study. *Lancet*. 2009;374(9702):1677 10.1016/S0140-6736(09)61457-4. [PubMed: 19878986] ••This follow-up study of participants in the Diabetes Prevention Program clinical trial demonstrated durable reductions in diabetes incidence with both intensive lifestyle intervention and metformin.
14. Gong Q, Gregg EW, Wang J, An Y, Zhang P, Yang W, et al. Long-term effects of a randomised trial of a 6-year lifestyle intervention in impaired glucose tolerance on diabetes-related microvascular complications: the China Da Qing diabetes prevention outcome study. *Diabetologia*. 2011;54(2):300–7. 10.1007/s00125-010-1948-9. [PubMed: 21046360]
15. Li G, Zhang P, Wang J, An Y, Gong Q, Gregg EW, et al. Cardiovascular mortality, all-cause mortality, and diabetes incidence after lifestyle intervention for people with impaired glucose tolerance in the Da Qing diabetes prevention study: a 23-year follow-up study. *Lancet Diabetes Endocrinol*. 2014;2(6):474–80. 10.1016/S2213-8587(14)70057-9. [PubMed: 24731674]

16. Diabetes Prevention Program Research Group. Long-term effects of lifestyle intervention or metformin on diabetes development and microvascular complications over 15-year follow-up: the diabetes prevention program outcomes study. *Lancet Diabetes Endocrinol.* 2015;3(11):866–75. 10.1016/s2213-8587(15)00291-0. [PubMed: 26377054]
17. Herman WH, Hoerger TJ, Brandle M, Hicks K, Sorensen S, Zhang P, et al. The cost-effectiveness of lifestyle modification or metformin in preventing type 2 diabetes in adults with impaired glucose tolerance. *Ann Intern Med.* 2005;142(5):323–32. [PubMed: 15738451]
18. Hafez D, Fedewa A, Moran M, O'Brien M, Ackermann R, Kullgren JT. Workplace interventions to prevent type 2 diabetes mellitus: a narrative review. *Curr Diab Rep.* 2017;17(2):9 10.1007/s11892-017-0840-0. [PubMed: 28150162] ••The paper reviewed the literature on employer-based programs aimed at preventing type 2 diabetes among adults, both those following the Diabetes Prevention Program curriculum and alternate intervention models.
19. American Diabetes Association. Standards of Medical Care in Diabetes-2018. *Diabetes Care.* 2018;41(Suppl 1):S1–S150. [PubMed: 29222369] •This paper outlines expert guidelines for diabetes screening, prevention, and management that are updated annually.
20. Handelsman Y, Bloomgarden ZT, Grunberger G, Umpierrez G, Zimmerman RS, Bailey TS, et al. American Association of Clinical Endocrinologists and American College of endocrinology—clinical practice guidelines for developing a diabetes mellitus comprehensive care plan - 2015. *Endocr Pract.* 2015;21(Suppl 1): 1–87. 10.4158/ep15672.gl. [PubMed: 25869408]
21. Centers for Medicare & Medicaid Services. Medicare Provides Coverage of Diabetes Screening Tests. Medicare-Learning-Network-MLN, American Medical Association, Baltimore, MD 2018 <https://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNMattersArticles/downloads/se0821.pdf>. Accessed July 31 2018.
22. Lenters-Westra E, Slingerland RJ. Three of 7 hemoglobin A1c point-of-care instruments do not meet generally accepted analytical performance criteria. *Clin Chem.* 2014;60(8):1062–72. 10.1373/clinchem.2014.224311. [PubMed: 24865164]
23. Hirst JA, McLellan JH, Price CP, English E, Feakins BG, Stevens RJ, et al. Performance of point-of-care HbA1c test devices: implications for use in clinical practice—a systematic review and meta-analysis. *Clin Chem Lab Med.* 2017;55(2):167–80. 10.1515/cclm-2016-0303. [PubMed: 27658148]
24. Bowen ME, Xuan L, Lingvay I, Halm EA. Performance of a random glucose case-finding strategy to detect undiagnosed diabetes. *Am J Prev Med.* 2017;52(6):710–6. 10.1016/j.amepre.2017.01.023. [PubMed: 28279547] ••This analysis of NHANES data examines the clinical performance (i.e. sensitivity and specificity) of using random glucose to identify cases of undiagnosed diabetes and compares performance with commonly used U.S. diabetes screening guidelines.
25. Steyerberg EW. *Clinical prediction models : a practical approach to development, validation, and updating.* New York, NY: Springer; 2009.
26. American Diabetes Association. Diabetes Risk Test. American Diabetes Association, Alexandria, VA 2018 <http://main.diabetes.org/dorg/PDFs/risk-test-paper-version.pdf>. Accessed July 26 2018.
27. Bang H, Edwards AM, Bomback AS, Ballantyne CM, Brillon D, Callahan MA, et al. Development and validation of a patient self-assessment score for diabetes risk. *Ann Intern Med.* 2009;151:775–83. 10.7326/0003-4819-151-11-200912010-00005. [PubMed: 19949143]
28. National Diabetes Prevention Program. CDC prediabetes screening test. Centers for Disease Control and Prevention 2016 <http://www.cdc.gov/diabetes/prevention/pdf/prediabetestest.pdf>. Accessed July 31 2018.
29. Bullard KM, Ali MK, Imperatore G, Geiss LS, Saydah SH, Albu JB, et al. Receipt of glucose testing and performance of two US diabetes screening guidelines, 2007–2012. *PLoS One.* 2015;10(4): e0125249. 10.1371/journal.pone.0125249.
30. O'Brien MJ, Bullard KM, Zhang Y, Gregg EW, Carnethon MR, Kandula NR, et al. Performance of the 2015 US Preventive Services Task Force Screening Criteria for Prediabetes and Undiagnosed Diabetes. *J Gen Intern Med.* 2018; 10.1007/s11606-018-4436-4. ••This analysis of NHANES data examines the clinical performance of the 2015 USPSTF screening criteria for identifying U.S. adults with prediabetes and diabetes, including estimates of sensitivity and specificity by racial/ethnic groups.

31. Wilson PW, Meigs JB, Sullivan L, Fox CS, Nathan DM, D'Agostino RB Sr. Prediction of incident diabetes mellitus in middle-aged adults: the Framingham offspring study. *Arch Intern Med.* 2007;167(10):1068–74. 10.1001/archinte.167.10.1068. [PubMed: 17533210]
32. Mann DM, Bertoni AG, Shimbo D, Carnethon MR, Chen H, Jenny NS, et al. Comparative validity of 3 diabetes mellitus risk prediction scoring models in a multiethnic US cohort. *Am J Epidemiol.* 2010;171(9):980–8. 10.1093/aje/kwq030. [PubMed: 20375194]
33. Kahn HS, Cheng YJ, Thompson TJ, Imperatore G, Gregg EW. Two risk-scoring systems for predicting incident diabetes mellitus in US adults age 45 to 64 years. *Ann Intern Med.* 2009;150(11):741. [PubMed: 19487709]
34. Schmidt MI, Duncan BB, Bang H, Pankow JS, Ballantyne CM, Golden SH, et al. Identifying individuals at high risk for diabetes: the atherosclerosis risk in communities study. *Diabetes Care.* 2005;28(8):2013–8. [PubMed: 16043747]
35. Mainous AG 3rd, Diaz VA, Everett CJ. Assessing risk for development of diabetes in young adults. *Ann Fam Med.* 2007;5(5):425–9. 10.1370/afm.705. [PubMed: 17893384]
36. Noble D, Mathur R, Dent T, Meads C, Greenhalgh T. Risk models and scores for type 2 diabetes: systematic review. *BMJ.* 2011;343: d7163. 10.1136/bmj.d7163. •This systematic review of diabetes risk models evaluates the large body of literature on predicting diabetes risk, while highlighting opportunities and challenges to their implementation in practice.
37. Collins GS, Mallett S, Omar O, Yu LM. Developing risk prediction models for type 2 diabetes: a systematic review of methodology and reporting. *BMC Med.* 2011;9:103 10.1186/1741-7015-9-103. [PubMed: 21902820]
38. American Medical Association. Prevent Diabetes STAT. 2015 <https://preventdiabetesstat.org/>. Accessed July 26 2018.
39. Nhim K, Khan T, Gruss SM, Wozniak G, Kirley K, Schumacher P, et al. Primary care providers' prediabetes screening, testing, and referral behaviors. *Am J Prev Med.* 2018;55(2):e39–47. 10.1016/j.amepre.2018.04.017. [PubMed: 29934016]
40. Noble D, Mathur R, Dent T, Meads C, Greenhalgh T. Risk models and scores for type 2 diabetes: systematic review. *BMJ.* 2011;343: d7163.
41. Ealovega MW, Tabaei BP, Brandle M, Burke R, Herman WH. Opportunistic screening for diabetes in routine clinical practice. *Diabetes Care.* 2004;27(1):9–12. [PubMed: 14693958]
42. O'Brien MJ, Lee JY, Carnethon MR, Ackermann RT, Vargas MC, Hamilton A, et al. Detecting dysglycemia using the 2015 United States Preventive Services Task Force Screening Criteria: a cohort analysis of community health center patients. *PLoS Med.* 2016;13(7):e1002074. 10.1371/journal.pmed.1002074. •This national analysis of EHR data from safety-net community health centers evaluates the clinical performance of the 2015 USPSTF diabetes screening criteria in a minority-predominant patient population.
43. Bowen ME, Merchant Z, Abdullah K, Bhat D, Fish J, Halm EA. Patient, provider, and system factors associated with failure to follow-up elevated glucose results in patients without diagnosed diabetes. *Health Serv Res Manag Epidemiol.* 2017;4: 2333392817721647. 10.1177/2333392817721647.
44. Bowen ME, Xuan L, Lingvay I, Halm EA. Random blood glucose: a robust risk factor for type 2 diabetes. *J Clin Endocrinol Metab.* 2015;100(4):1503–10. 10.1210/jc.2014-4116. [PubMed: 25650899] ••This study uses NHANES data to describe the association between non-diagnostic random glucose values and undiagnosed type 2 diabetes and prediabetes in the U.S. population.
45. Bowen ME, Xuan L, Lingvay I, Halm EA. Doc, I just ate: interpreting random blood glucose values in patients with unknown glycemic status. *J Gen Intern Med.* 2018;33(2):142–4. 10.1007/s11606-017-4213-9. [PubMed: 29134572]
46. Bowen ME, Sanders J, Zhang S, Santini NO, Lingvay I, Halm E. Derivation of an EMR-based dysglycemia risk score. *Diabetes.* 2018;67(Supplement 1) 10.2337/db18-1497-P
47. Selvin E, Wang D, Matsushita K, Grams ME, Coresh J. Prognostic implications of single-sample confirmatory testing for undiagnosed diabetes: a prospective cohort study *Ann Intern Med.* 2018; 10.7326/M18-0091. •This study supports the concurrent measurement of hemoglobin A1c and fasting glucose on a single blood sample to identify undiagnosed diabetes and confirm diagnosis.

48. Simmons RK, Echouffo-Tcheugui JB, Sharp SJ, Sargeant LA, Williams KM, Prevost AT, et al. Screening for type 2 diabetes and population mortality over 10 years (ADDITION-Cambridge): a cluster-randomised controlled trial. *Lancet*. 2012;380(9855): 1741–8. 10.1016/s0140-6736(12)61422-6. [PubMed: 23040422]
49. Law M “Opportunistic” screening. *J Med Screen*. 1994;1(4):208. [PubMed: 8790520]
50. Whitley HP, Hanson C, Parton JM. Systematic diabetes screening using point-of-care HbA1c testing facilitates identification of Prediabetes. *Ann Fam Med*. 2017;15(2):162–4. 10.1370/afm.2035. [PubMed: 28289117]
51. Herman WH, Taylor GW, Jacobson JJ, Burke R, Brown MB. Screening for prediabetes and type 2 diabetes in dental offices. *J Public Health Dent*. 2015;75(3):175–82. 10.1111/jphd.12082. [PubMed: 25662777]
52. Krass I, Carter R, Mitchell B, Mohebbi M, Shih STF, Trinder P, et al. Pharmacy diabetes screening trial: protocol for a pragmatic cluster-randomised controlled trial to compare three screening methods for undiagnosed type 2 diabetes in Australian community pharmacy. *BMJ Open*. 2017;7(12):e017725. 10.1136/bmjopen-2017-017725.
53. Siu AL. Screening for abnormal blood glucose and type 2 diabetes mellitus: U.S. preventive services task force recommendation statement. *Ann Intern Med*. 2015;163(11):861–8. 10.7326/m15-2345. [PubMed: 26501513] •This paper is the full report outlining the most recent diabetes screening guideline by the USPSTF.
54. Piper MA, Evans CV, Burda BU, Margolis KL, O'Connor E, Whitlock EP. Diagnostic and predictive accuracy of blood pressure screening methods with consideration of rescreening intervals: a systematic review for the U.S. preventive services task force. *Ann Intern Med*. 2015;162(3):192–204. 10.7326/m14-1539. [PubMed: 25531400]
55. Ali MK, Echouffo-Tcheugui J, Williamson DF. How effective were lifestyle interventions in real-world settings that were modeled on the diabetes prevention program? *Health Aff (Millwood)*. 2012;31(1):67–75. 10.1377/hlthaff.2011.1009. [PubMed: 22232096]
56. Dunkley AJ, Bodicoat DH, Greaves CJ, Russell C, Yates T, Davies MJ, et al. Diabetes prevention in the real world: effectiveness of pragmatic lifestyle interventions for the prevention of type 2 diabetes and of the impact of adherence to guideline recommendations: a systematic review and meta-analysis. *Diabetes Care*. 2014;37(4): 922–3. 10.2337/dc13-2195/-ZDC1. [PubMed: 24652723]
57. Mudaliar U, Zabetian A, Goodman M, Echouffo-Tcheugui JB, Albright AL, Gregg EW, et al. Cardiometabolic risk factor changes observed in diabetes prevention programs in US settings: a systematic review and meta-analysis. *PLoS Med*. 2016;13(7):e1002095. 10.1371/journal.pmed.1002095.
58. Haw JS, Galaviz KI, Straus AN, Kowalski AJ, Magee MJ, Weber MB, et al. Long-term sustainability of diabetes prevention approaches: a systematic review and meta-analysis of randomized clinical trials. *JAMA Intern Med*. 2017;177(12):1808–17. 10.1001/jamainternmed.2017.6040. [PubMed: 29114778]
59. Azar KM, Xiao L, Ma J. Baseline obesity status modifies effectiveness of adapted diabetes prevention program lifestyle interventions for weight management in primary care. *Biomed Res Int*. 2013;2013:191209–7. 10.1155/2013/191209.
60. Sepah SC, Jiang L, Peters AL. Translating the diabetes prevention program into an online social network: validation against CDC standards. *Diabetes Educ*. 2014;40(4):435–43. 10.1177/0145721714531339. [PubMed: 24723130]
61. Trief PM, Weinstock RS, Cibula D, Delahanty LM. Sustained weight loss one year after group telephone intervention: 3-year results from the SHINE study. *Diabetes Res Clin Pract*. 2014;106(3):e74–8. 10.1016/j.diabres.2014.09.032. [PubMed: 25451907]
62. Chen F, Su W, Becker SH, Payne M, Castro Sweet CM, Peters AL, et al. Clinical and economic impact of a digital, remotely-delivered intensive behavioral counseling program on Medicare beneficiaries at risk for diabetes and cardiovascular disease. *PLoS One*. 2016;11(10):e0163627. 10.1371/journal.pone.0163627.
63. Vadheim LM, Patch K, Brokaw SM, Carpenedo D, Butcher MK, Helgersson SD, et al. Telehealth delivery of the diabetes prevention program to rural communities. *Transl Behav Med*. 2017;7(2): 286–91. 10.1007/s13142-017-0496-y. [PubMed: 28417426]

64. LeFevre ML, U. S. Preventive services task force. Behavioral counseling to promote a healthful diet and physical activity for cardiovascular disease prevention in adults with cardiovascular risk factors: U.S. preventive services task force recommendation statement. *Ann Intern Med*. 2014;161(8):587–93. 10.7326/M14-1796. [PubMed: 25155419]
65. Diabetes Prevention Program Research Group. The diabetes prevention program: design and methods for a clinical trial in the prevention of type 2 diabetes. *Diabetes Care*. 1999;22(4):623–34. [PubMed: 10189543]
66. Marrero DG, Palmer KN, Phillips EO, Miller-Kovach K, Foster GD, Saha CK. Comparison of commercial and self-initiated weight loss programs in people with Prediabetes: a randomized control trial. *Am J Public Health*. 2016;106(5):949–56. 10.2105/ajph.2015.303035. [PubMed: 26890171]
67. Albright AL, Gregg EW. Preventing type 2 diabetes in communities across the US: the National Diabetes Prevention Program. *Am J Prev Med*. 2013;44(4):S346–S51. [PubMed: 23498297]
68. Vojta D, Koehler TB, Longjohn M, Lever JA, Caputo NF. A coordinated national model for diabetes prevention: linking health systems to an evidence-based community program. *Am J Prev Med*. 2013;44(4 Suppl 4):S301–6. 10.1016/j.amepre.2012.12.018. [PubMed: 23498291]
69. YMCA's Diabetes Prevention Program. Diabetes prevention program FACT SHEET: January 2018. YMCA of the USA: Chicago, IL; 2018.
70. Center for Disease Control and Prevention. National Diabetes Prevention Program. U.S. Department of Health and Human Services, Atlanta, GA 2018 <https://www.cdc.gov/diabetes/prevention/index.html>. Accessed July 31 2018.
71. Ely EK, Gruss SM, Luman ET, Gregg EW, Ali MK, Nhim K, et al. A national effort to prevent type 2 diabetes: participant-level evaluation of CDC's national diabetes prevention program. *Diabetes Care*. 2017;40(10):1331–41. 10.2337/dc16-2099. [PubMed: 28500215] •This study analyzed data from 14,747 participants in the DPP nationwide, including those who enrolled from 2012–2016.
72. Vanderwood KK, Hall TO, Harwell TS, Butcher MK, Helgersson SD. Implementing a state-based cardiovascular disease and diabetes prevention program. *Diabetes Care*. 2010;33(12):2543–5. 10.2337/dc10-0862. [PubMed: 20805260]
73. Brokaw SM, Carpenedo D, Campbell P, Butcher MK, Furshong G, Helgersson SD, et al. Effectiveness of an adapted diabetes prevention program lifestyle intervention in older and younger adults. *J Am Geriatr Soc*. 2015;63(6):1067–74. 10.1111/jgs.13428. [PubMed: 26031428]
74. Moin T, Damschroder LJ, AuYoung M, Maciejewski ML, Datta SK, Weinreb JE, et al. Diabetes prevention program translation in the veterans health administration. *Am J Prev Med*. 2017;53(1):70–7. 10.1016/j.amepre.2016.11.009. [PubMed: 28094135]
75. Tseng E, Yeh HC, Maruthur NM. Metformin use in Prediabetes among U.S. adults, 2005–2012. *Diabetes Care*. 2017;40(7):887–93. 10.2337/dc16-1509. [PubMed: 28373205]
76. Schmittiel JA, Gopalan A, Lin MW, Banejee S, Chau CV, Adams AS. Population health management for diabetes: health care system-level approaches for improving quality and addressing disparities. *Curr Diab Rep*. 2017;17(5):31 10.1007/s11892-017-0858-3. [PubMed: 28364355] ••This narrative review highlights the role of several strategies to improve population-level management of type 2 diabetes, including electronic health record tools, practice redesign, and new payment models.
77. Moin T, Li J, Duru OK, Ettner S, Turk N, Keckhafer A, et al. Metformin prescription for insured adults with prediabetes from 2010 to 2012: a retrospective cohort study. *Ann Intern Med*. 2015;162(8):542–8. 10.7326/M14-1773. [PubMed: 25894024]
78. Desai JR. Reducing CV Risk in Prediabetes patients using EHR-based decision support. National Institutes of Health, U.S. Department of Health and Human Services, Research Portfolio Online Reporting Tools 2018 https://projectreporter.nih.gov/project_info_description.cfm?aid=9327055&icde=40170194. Accessed July 31 2018.
79. National Association of Chronic Disease Directors (NACDD), Leavitt Partners L. Advancing Chronic Disease Prevention and Management Programs: Building a Third-Party Organization to Support Managed Care Coverage of Services in Community-Based Organizations in Illinois. Atlanta, GA 2018.

80. Nowinski Konchak J, Moran MR, O'Brien MJ, Kandula NR, Ackermann RT. The state of diabetes prevention policy in the USA following the Affordable Care Act. *Curr Diab Rep.* 2016;16(6):55 10.1007/s11892-016-0742-6. [PubMed: 27145778] •This paper highlighted all provisions of the Affordable Care Act that may promote diabetes prevention, including gaps and opportunities in current practice.

Fig. 1.

A framework for population-based diabetes screening and prevention

Table 1**Stakeholders in US population-level diabetes screening and prevention**

Activity	Stakeholders ^a	Possible action(s)
Diabetes risk assessment	Individuals	Complete diabetes risk questionnaires Communicate risk concerns to healthcare providers
	Community-based organizations	Distribute diabetes risk questionnaires to community members Assess social risk factors for diabetes
	Healthcare providers and clinics	Distribute diabetes risk questionnaires to patients Act on elevated random glucose results
	Healthcare systems	Promote system-wide use of risk assessment practices (e.g. diabetes risk questionnaires, use of random glucose results, creation of prediabetes registries)
	Professional organizations (e.g., AMA ^b)	Media campaigns Raise awareness of diabetes risk by promoting use of questionnaires Advocate for diabetes risk assessment practices among healthcare providers
Diabetes screening	Public health agencies (e.g., CDC ^c)	Media campaigns Raise awareness of diabetes risk by promoting use of questionnaires
	Individuals	Request healthcare provider to order screening tests Complete screening tests
	Healthcare providers	Order screening tests Communicate results to patients Repeat screening as clinically indicated
	Healthcare systems	Promote system-wide policies for diabetes screening Develop clinical decision support to facilitate screening among eligible adults
	Professional organizations (e.g., AACE ^d , ADA ^e)	Make screening guidelines
Prediabetes treatment	Governmental organizations (e.g., USPSTF ^f , HHS ^g)	Advocate for screening in community and clinical settings Make screening guidelines
		Drive health policy coverage for screening Attend DPP program ^h Take metformin
	Individuals	Deliver DPP program Address social risk factors for diabetes
	Community-based organizations	Refer patients with prediabetes to DPP programs Prescribe metformin
	Healthcare providers	

Activity	Stakeholders ^a	Possible action(s)
	Healthcare systems	Develop partnerships with community-based DPP providers for referral and information exchange
	Public health agencies (e.g., CDC's NDPP program) ⁱ	Formation of DPP programs as part of Accountable Care Organizations and employee wellness programs
	Third-party administrators	Training/workforce development for delivering DPP
		Recognition program for DPP delivery sites
		Analyzing and reporting outcomes at the population level
		Connect eligible individuals with DPP programs
		Maintain and report DPP data for recognition/certification of programs
		Assist DPP providers with billing for eligible participants

^aUS employers are a stakeholder in diabetes screening and prevention, but are not included here because their role has been reviewed in-depth elsewhere [18••]

^bAmerican Medical Association

^cCenters for Disease Control and Prevention

^dAmerican Association of Clinical Endocrinologists

^eAmerican Diabetes Association

^fUnited States Preventive Services Task Force

^gUS Department of Health and Human Services

^hDiabetes Prevention Program

ⁱNational Diabetes Prevention Program

Table 2

Strategies for diabetes risk assessment

Strategy	Target group	Setting(s) for application	Risk factors	Eligible US adult population, % ^a	Performance characteristics
Diabetes risk scores					
ADA Diabetes Risk Test [26]	Individuals	Community, clinic	Age, sex, gestational diabetes, family history of diabetes, hypertension, overweight/obesity, physical inactivity	35 [27]	Sensitivity 79%; specificity 67% [27]
CDC Prediabetes Test [28]	Individuals	Community, Clinic	Age, child with macrosomia, age, physical inactivity, overweight/obesity	Unknown	No available evidence
Random blood glucose	Healthcare providers	Clinic	Serum glucose 100 mg/dL	23 [24••]	Sensitivity 81.6%; specificity 78.0% [24••]
Diabetes screening guidelines					
AACE/ACE screening criteria	Healthcare providers	Clinic	Age 45 years, overweight/obesity, minority race/ethnicity, hypertension, dyslipidemia, history of cardiovascular disease, family history of diabetes, physical inactivity, history of gestational diabetes or baby weighing > 9 lb. or polycystic ovary syndrome (women only), impaired glucose tolerance, impaired fasting glucose, metabolic syndrome, acanthosis nigricans, non-alcoholic fatty liver disease, chronic glucocorticoid exposure, sleep disorders, antipsychotic therapy for schizophrenia and/or severe bipolar disease	Unknown	No available evidence
ADA screening criteria	Healthcare providers	Clinic	Age 45 years, overweight/obesity, minority race/ethnicity, hypertension, dyslipidemia, history of cardiovascular disease, acanthosis nigricans, physical inactivity, family history of diabetes, history of gestational diabetes or baby weighing > 9 lb. or polycystic ovary syndrome (women only), impaired fasting glucose, impaired glucose tolerance, elevated hemoglobin A1c (5.7%)	73 [29]	Sensitivity 88.8%; specificity 13.5% [29]
USPSTF screening criteria	Healthcare providers	Clinic	Age 40–70 years, overweight/obesity	34 [24••]	Sensitivity 65.2%; specificity 66.5% [24••]

AACE American Association of Clinical Endocrinologists, ACE American College of Endocrinology, ADA American Diabetes Association, USPSTF US Preventive Services Task Force

^aProportion of the US population eligible for diabetes screening according to the screening strategy