The majority of employees in the United States have laboratory evidence of chronic disease, and 1 in 3 is likely to have unidentified disease. Chronic diseases, including cardiovascular disease (CVD), diabetes, cancer, and chronic kidney disease (CKD), present a substantial and growing economic burden to large employers in that annual per capita expenditures for persons with chronic disease are 2.3-fold higher (for diabetes) to 10-fold higher (for advanced CKD) than for those without chronic disease. Early detection of and care for chronic diseases enabled by health screening can reduce morbidity and mortality and avoid the higher costs of advanced disease. For example, all-cause costs of a person with CKD increase dramatically as the disease advances in stage, from $26,843 per year for stage 3 to $76,969 per year for stages 4 and 5 and $121,948 per year for end-stage renal disease (ESRD), with up to $88,000 per year for hemodialysis.

In addition to incurring healthcare costs, employees experiencing poor health may experience absence, short-term disability, and lower productivity. Without intervention, the chronic disease burden in the US workforce is expected to rise. Fortunately, chronic diseases can be prevented, delayed, or alleviated. The CDC estimates that as much as 80% of heart disease, stroke, and type 2 diabetes cases and 40% of cancer cases could be prevented through modification of lifestyle behaviors. Moreover, most employers (>90%) believe that their healthcare costs could be reduced by improvements in healthy behaviors. Although most large employers (70%-85%) offer basic health screenings, less than 25% provide a comprehensive worksite population health program that includes comprehensive health screening, access to related health improvement programs, and an environment that supports health.

Employer-sponsored annual health screenings offer an opportunity to facilitate the delivery of population health; the identification of health risk factors offers early opportunities for intervention and connection to care. However, general wellness programs have generated mixed evidence, given the broad variation in program designs, organizational settings, and diverse populations in which they are implemented. Evidence-informed programs based on the identification of prediabetes, diabetes, CKD, or colorectal cancer
in their early stages may enable more targeted and successful programs that offer early treatment and care that can slow or prevent disease development and debilitating and costly health outcomes. Of all participants in a population health screening with evidence of diabetes, 28% were previously unrecognized, and of all participants with laboratory evidence of CKD, 89% were previously unrecognized. In addition, colorectal cancer screening via stool testing for hemoglobin may increase detection of lesions due to higher acceptance of the test method and a participation rate 40% higher than that of colonoscopy. However, the longitudinal impact of annual health screenings on disease progression and health outcomes is largely unknown. Thus, the purpose of this analysis was to evaluate the projected value of annual health screenings in 35,258 employees and spouses who participated in annual health screenings in 2017 for early detection of prediabetes, diabetes, evidence of CKD, and hemoglobin in stool on disease outcomes and progression.

**METHODS**

Laboratory evidence of prediabetes incidence and diabetes incidence was assessed in 35,254 employees and spouses of a single employer who participated in annual health screenings in 2017. Prediabetes was defined as having a glycated hemoglobin (A1C) measurement between 5.7% and 6.4% or a fasting glucose (FG) measurement between 100 mg/dL and 125 mg/dL. Diabetes was defined having an A1C higher than 6.4% or FG higher than 125 mg/dL. Newly identified prediabetes was defined as prediabetes in 2017 without evidence of diabetes or prediabetes in the prior year. Newly identified diabetes was defined as diabetes in 2017 without evidence of diabetes in the prior year. Cases of diabetes prevented by intervention and care were projected based on results of the Diabetes Prevention Program. Expected incidence of CVD and microvascular complications (retinopathy, nephropathy, and neuropathy) were projected based on previous reports.

Laboratory evidence of new-onset CKD incidence was assessed in employees and spouses who participated in annual health screenings in 2017 (35,258 participants). Evidence of CKD was defined as a single estimated glomerular filtration rate (eGFR) measurement of less than 60 mL/min/1.73 m² without CKD in the prior year. Confirmed evidence of CKD and progression rate to stages 4 and 5 disease and ESRD were projected based on previous research.

Colorectal cancer screening was offered to eligible employees and spouses aged 50 to 75 years who participated in annual health screenings between 2013 and 2017 (18,976 tests). A positive screening test was determined by the evidence of hemoglobin in the stool from a fecal immunological test (FIT), InSure FIT (Clinical Genomics; Bridgewater, New Jersey). Follow-up colonoscopy results and stage distribution were based on prior research.

**RESULTS**

Screening for prediabetes (A1C of 5.7%-6.4% or FG of 100-125 mg/dL) identified 1185 (11.9%) cases not recognized in the previous year (previously unrecognized) per 10,000 individuals screened. Based on the Diabetes Prevention Program results, we estimate that for every 1000 confirmed prediabetes cases, 210 diabetes cases can be prevented over 5 years (Table 1). Screening of employees and spouses found that for every 10,000 participants, 287 (2.9%) had previously unrecognized hyperglycemia (laboratory evidence of diabetes; A1C >6.4% or FG >125 mg/dL). Using previous reports of CVD incidence and microvascular complications (retinopathy, nephropathy, and neuropathy), we estimated that within 1 year, for every 1000 patients with confirmed diabetes, about 105 would experience complications (Table 2). Annual screening of employees and spouses found that for every 10,000 participants, 146 (1.46%) had previously unrecognized hyperglycemia.
low eGFR (<60 mL/min/1.73 m²) (Table 3). Similar rates have been observed in patients screened in primary care settings. Prior research suggests that approximately 50% of initial low eGFR findings are confirmed as CKD upon follow-up. Considering the progression rate from CKD to ESRD observed in the Alberta Kidney Disease Network, we predicted that for every 1000 cases of confirmed CKD, about 7 patients would progress to ESRD within a year and about 34 within 5 years (Table 3). In addition, based on previous research, 136 would be expected to progress to stage 4 or stage 5 (of 5 stages) over 5 years.

Annual screening for colorectal cancer resulted in a positive screening test rate of 6.7% (Table 4). For every 10,000 FIT tests evaluated, 669 had a positive result. Assuming that 78% of those with a positive test have a follow-up colonoscopy (n = 525), we estimate subsequent diagnosis of 263 adenomas (some considered precancerous) and 14 colorectal cancers. Assuming a similar stage distribution to profiles observed in other FIT-based screening studies, we estimate that the 14 colorectal cancers detected would be made up of 6 stage I, 4 stage II, and 4 stage III cases (of 4 stages). We also assume that the screen-dependent shift toward earlier-stage detection would result in 3 more stage I cancers and 1 fewer stage II cancer and 2 fewer stage IV cancers being diagnosed than would have been the case without screening.

**DISCUSSION**

**Prediabetes**

Early detection of prediabetes is important because type 2 diabetes can be present for 9 to 12 years before being diagnosed and, as a result, complications are often present at the time of diagnosis. Without detection and early intervention, 4% to 19% of those with prediabetes develop diabetes each year, depending on the population and criteria. A1C and FG are accepted methods for prediabetes screening and diagnosis of diabetes. We recently reported that elevated A1C in working-age individuals with normal FG in an employee wellness program was associated with 2- to 8-fold greater odds of incident diabetes within 4 years.
Fortunately, lifestyle interventions are effective in reducing incidence of diabetes.12,20 Lifestyle interventions may reduce incidence of diabetes by up to 58% over 3 years.14,23 Prior research has similarly shown the effectiveness of employer-based health screening for diabetes and prediabetes,26 but benefits depend on many factors. Benefits of diabetes prevention are greater when diabetes risk is detected early.42 Thus, in addition to disease prevention, prompt screening and intervention is associated with reduced absolute and relative risk and all-cause mortality at 5 years compared with a 3-year delay in diagnosis.42

Medical costs of prediabetes and undiagnosed diabetes are approximately $510 and $4030 per year per person, respectively.2 When prediabetes progresses to diabetes, people with diagnosed diabetes, on average, have medical expenditures approximately 2.3 times higher than they would be in the absence of diabetes.24 In addition, indirect costs associated with absence, productivity, and disability further exacerbate the costs of chronic health conditions.24 The American Diabetes Association quantified the estimated cost of diagnosed diabetes in the United States in 2017 as $327 billion, including $237 billion (72%) in direct medical costs and $90 billion (28%) in reduced productivity.44

**Diabetes**

Poor management of diabetes can be associated with disease-related complications such as CVD, nephropathy, retinopathy, and neuropathy, which can lead to chronic morbidities and mortality.14,16 More than 20% of diabetes in the United States is undiagnosed,50 and risk of complications is associated with diabetes duration.46 Detection and treatment that is delayed by 3 years has been shown to translate into 40% higher 5-year CVD risk (11.2% vs 7.9%) and 20% higher incidence of all-cause mortality (7.2% vs 6.0%).41 In addition, risk for cardiovascular events or vascular events is 11% to 16% higher with every 1% increase in A1C79,84 or 18 mg/dL (1 mmol/L) increase in FG greater than 100 mg/dL.75,80 Thus, detection and care may reduce CVD and microvascular complications, including retinopathy, neuropathy, and nephropathy. Average lifetime medical costs for an individual with diabetes have been estimated at $85,200, of which 53% is due to treating diabetic complications.41 Per-year medical costs for a person with diabetes are approximately $16,750, and about $9600 to $10,970 of these costs are attributed to diabetes.2,24

**CKD**

Progression of CKD can be slowed when it is detected in the early stages.42-44 Early identification, intervention, and referral to a nephrologist are essential to slow progression of CKD and avoid complications of ESRD.42-44 Typically, a multifactorial treatment approach is advocated to treat the causes and consequences of CKD, slow CKD progression, and avoid ESRD.41 As hypertension and type 2 diabetes are the major causes of CKD and are important treatment targets, it is possible to attenuate disease progression and slow reductions in eGFR with proactive treatment.44 Progression rates of CKD vary with annual reductions in kidney function ranging from 2 mL/
less costly compared with other options. Moreover, newer FIT tests offer greater simplicity and sensitivity relative to historical fecal occult guaiac-based blood tests while remaining relatively inexpensive compared with other diagnostic screening modalities at $20 to $50 per kit.

Limitations

A few limitations to the study should be considered when interpreting the study findings. First, although the study reflects data from a large workforce, the study population may not necessarily represent the demographics of all employers. Second, participation in the annual health screening program was voluntary, participation reflected about 65% of the entire pool of employees and spouses eligible to participate and might include those more likely to be engaged in their healthcare; however, this population is likely to reflect other employee wellness program populations. Third, the study is based on laboratory evidence of chronic disease and self-reported physician diagnosis, but physician diagnoses from health records were not available for study; thus, definite diagnoses cannot be made. However, those identified based on laboratory evidence and self-reported diagnoses should provide a good indication of the fraction of participants who would benefit from additional follow-up. Despite these limitations, knowledge of previously unrecognized disease may enable health engagement and more positive health outcomes for individuals in a large population.

CONCLUSIONS

Population health screening identifies early evidence of unrecognized prediabetes, diabetes, CKD, and colorectal cancer in large populations to improve health trajectories. Early identification enables prompt treatment that can prevent disease progression and yield positive value on investment. This study provides quantification of unknown health risk for conditions that are not always screened for in employee populations66 and extrapolates the health impact and opportunity for an employee population. Provided data and insights may facilitate the delivery of population health programs to targeted employee segments—a strategy required to drive results.67 Driven by data, care pathways may narrow gaps in care and improve patient understanding, clinical outcomes, quality of life, and productivity, which may further benefit population health. As chronic diseases present a substantial and growing economic burden to large employers in regard to both healthcare costs and productivity, employer-sponsored annual health screenings may facilitate the delivery of population health.

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