

The impact of social determinants on Type 2 diabetes: An analytical study

Introduction

Over the past two decades, the rate of diabetes has doubled in the U.S., now ranking as the seventh leading cause of death.¹ The burden of this disease is not shared equally, however.

Research has shown that Type 2 diabetes (T2D) disproportionately affects marginalized populations, with the highest prevalence among people of color.²

These disparities are the manifestation of structural racism, concentrating vulnerabilities and risks among those with the least resources to cope. Among chronic diseases, T2D is particularly sensitive to interventions altering behavior and lifestyle, which have been the primary focus of interventions to date. Behavioral modification is particularly challenging, and yet only one part of the puzzle.

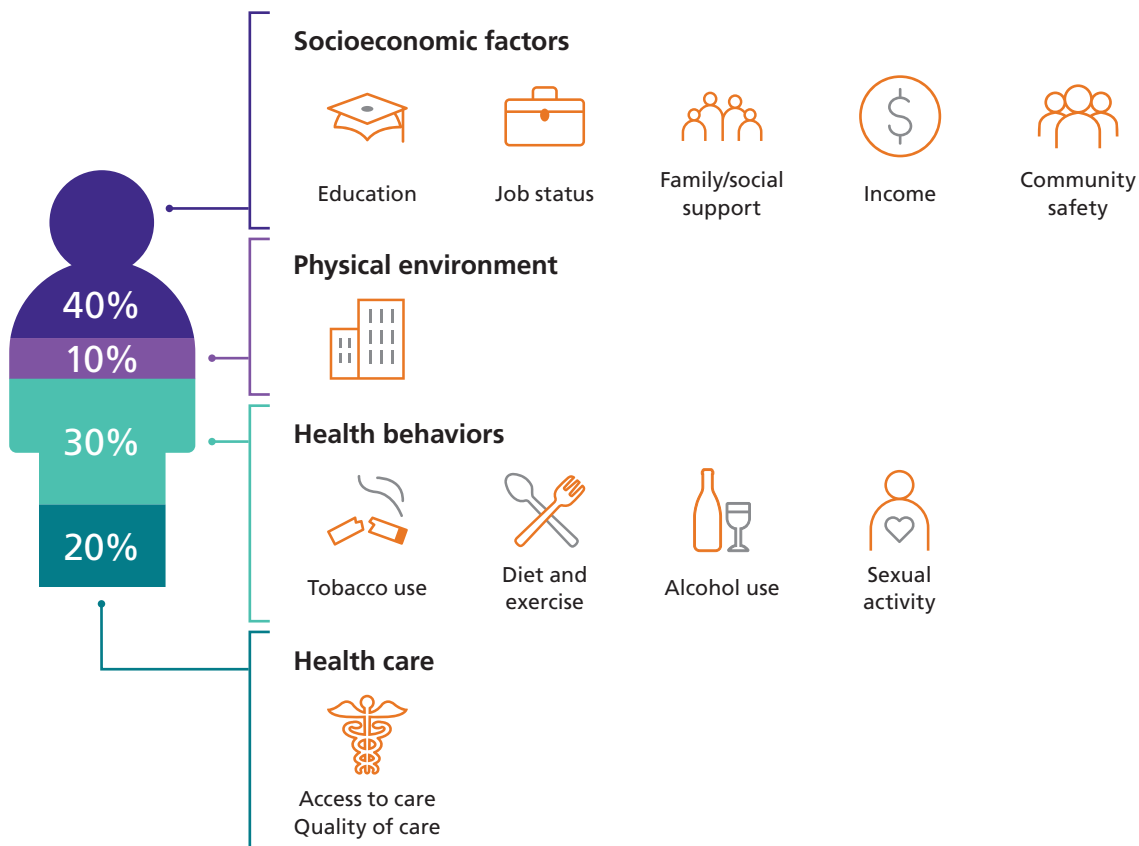


Figure 1: Determinants of health³

Key questions leaders are asking today:

- How do we stratify and identify members across a disease continuum from at-risk to end-of-life in a way that captures all the factors impacting health?
- How can we identify and address the impact of SDOH for our members with diabetes in a relevant and meaningful way at the individual and population level?
- What opportunities to help reduce the burden of diabetes are revealed with a whole person analytical approach?
- Are there opportunities to change the trajectory of diabetes in our membership through SDOH-based interventions?
- What are the most significant SDOH factors impacting Type 2 risk, severity and progression?
- How does SDOH contribute to progression of disease?
- How do SDOH risk factors vary across lines of business and disease progression?

There is overwhelming evidence indicating that social determinants of health (SDOH) account for roughly 80% of an individual's health outcomes (Figure 1).³ Though disparities are stratified socioeconomically, social barriers are commonly experienced across the population, with 68% of individuals experiencing at least one SDOH challenge at any given time.⁴ Thus, focusing on drivers of health beyond traditional health care is an important and underexplored part of disease management and prevention.

To date, the relationship between social determinants and T2D incidence and progression is not well understood. This study aimed to fill this gap, using the Robert Wood Johnson Foundation SDOH framework to show the relationships between upstream factors, such as race, ethnicity and socioeconomic status (SES), to midstream outcomes, such as housing and food security, to downstream health outcomes, such as incidence and progression of diabetes. The analysis included over 2 million members from a large Minnesota health plan with multiple lines of business and classified the correlational weight unique SDOH factors had on T2D incidence and progression.⁵

We posited that the risk of incidence and rate of progression would vary across individuals, and that unique SDOH factors would correlate to incidence, severity and progression to varying degrees. Here we review the current understanding of the impact unique SDOH factors have on T2D incidence and finally review the study background, findings and implications. Ultimately, the value in this work comes in the power of an integrated whole person analytics approach to tailor interventions, alter the course of disease incidence and progression, reduce costs, and ultimately improve health equity.

Diabetes by the numbers:

34.2 million
diabetic cases in the U.S.
in 2020⁵

90–95%
of diabetic cases are Type 2

\$327 billion
of annual health care costs are
attributed to diabetes

1 in 3
Americans are at risk of
developing diabetes, and
80–90% of these individuals
are unaware⁵

SDOH and Type 2 diabetes

Research on the impact of unique SDOH variables on T2D incidence is limited, but the most current understanding is listed below. While there is some understanding of the impact these variables have on T2D, there has not been research to date into the impact of changing SDOH factors and targeted interventions on T2D incidence or severity. Nor is the unique impact of individual variables well understood. Future work investigating these topics would provide a clearer understanding of the relationship between SDOH factors and T2D.



Income

Compared to high income Americans, those considered near poor and poor have rates of T2D 74% and 100% higher, respectively. At the neighborhood level, Census tracts with lower levels of average income have shown both a higher concentration of T2D, as well as a higher rate of individual progression from prediabetes to T2D. For adults with a family income below the federal poverty line, adults with T2D have a twofold higher risk of mortality due to T2D.⁶



Education

7.2% of adults with a college education have T2D compared to 12.6% of adults with less than high school education. Those with less than a high school education have rates of diabetes related mortality two times higher than college educated adults.⁶



Occupation

Research has shown that shift work increases T2D risk compared to consistent daytime hours. A separate analysis found that working >55 hrs per week was associated with a higher incident of T2D for adults with low SES but not adults with high SES.⁶



Geography

Location is another factor that contributes to incidence and progression of T2D. One study found that mothers who were given housing vouchers to move to low-poverty neighborhoods had HbA1c levels 21.6% lower than the control group in a 10 year follow-up study. Another found that poor individuals in poor neighborhoods had twice the rate of T2D compared to poor individuals in non-poor neighborhoods.⁶ The built environment similarly plays a large role on T2D. One study found that neighborhoods with a higher density of fast-food stores had a T2D incidence rate that was 32% higher, even after adjusting for individual factors. Another study found that neighborhoods with higher levels of greenspace had lower rates of T2D.⁶



Race

Black Americans are 60% more likely to be diagnosed with T2D compared to their white counterparts.³ In one study, women of color exposed to racism had a 31% higher risk of T2D compared to those who infrequently or never experienced racism, even after controlling for SES and other factors. Women with the highest exposure to a lifetime of structural racism via discrimination in work, housing, and police interactions had a 16% increased risk of developing T2D compared to women who had no experience of structural racism.⁶



Social isolation

Men living alone had a 94% higher rate of T2D compared to those cohabitating. Similarly, men that lacked social involvement in clubs or groups had 42% higher odds of T2D. For women, lack of social involvement was associated with 60% higher odds of prediabetes and 112% higher odds of T2D.⁷ Inversely, neighborhoods with higher levels of social cohesion (measured by trust, willingness to help, and the extent to which neighbors get along) was associated with a 22% lower rate of T2D.⁶

Study background

Given the significance of upstream and midstream factors on health outcomes, the foundational framework of this study was to use person level data to develop a whole person view of the individual, both in terms of clinical and non-clinical data (Figure 1). This framework was then applied to a member level dataset with 2.2 million members focusing specifically on T2D with the goal of identifying the most important clinical and nonclinical factors impacting T2D incidence and progression.

The primary focus of this study was on T2D progression and population level risk category. The progression categories included emerging, at risk and severe, noting that not everyone under analysis was at the same stage of progression within each category. It was postulated that upstream SDOH factors would vary for individuals along T2D progression and that as disease progresses, both the individual SDOH characteristics and an individual's sensitivity to those characteristics would vary by disease stage. In short, someone who was prediabetic would not have the same SDOH characteristics as someone with complex T2D, and those would impact individuals to different degrees. Within each progression category, it

was presumed that individual variations in SDOH vulnerability significantly mediated both the risk of T2D incidence and the rate of progression. Additionally, it was presumed that not all SDOH factors contribute equally to disease incidence, severity and progression, and that parsing apart the most significant drivers through whole person analytics would allow for more targeted and effective interventions. This type of analysis was only possible by having comprehensive, whole person data on individuals: SDOH, clinical and behavioral at each stage of T2D progression.

Lastly, incorporating propensity to engage with the health system, care management, and the ability to manage one's health gave a clearer picture of individual level differences. Integrating all of these factors provides a whole person analytical framework that produces actionable insights.

Figure 2 shows the analytical delivery framework that was leveraged to conduct the analysis and the type of deliverables that are associated within each stage. The next section discusses the results of the analysis and the output for the findings in each of these categories.²

	Framework category	Output
Integrated data	Integration of clinical, behavioral and SDOH data for a whole person view of those who fall within the diabetes progression spectrum	Person level connection of clinical, behavioral and SDOH dataset
Descriptive analytics	Understanding the populations' utilization, SDOH and cost data from a high level, with the ability to drill down	Tableau and GIS workbooks to identify opportunity areas for intervention
Diagnostic analytics	Correlation and regression modeling to identify significant factors (clinical/behavioral/SDOH) that correlate with diabetes progression	Correlation maps and decision tree analysis
Predictive analytics	Correlation and regression modeling to identify significant factors (clinical/behavioral/SDOH) that correlate with diabetes progression	What we know about the member impacts on their outcome
Prescriptive analytics	Identify, recommend and implement care management outreach campaigns to the identified patients; measure, adjust, deploy	How we can change outcomes: analytics, strategy and care delivery

Figure 2: Analytical delivery framework

Results and findings

Integrated analytics

To create a dataset that captured a whole-person point of view, person-level clinical, behavioral and SDOH data was integrated together. Rather than focusing only on high-cost, high-risk factors and individuals, focus was placed further upstream in the disease process to identify those that were at risk for developing severe T2D. Within this dataset person-level SDOH data consisted of financial insecurity, housing insecurity, social isolation and transportation insecurity. The T2D spectrum was segmented into the following three categories for the diagnostic analytics portion of this analysis:

1. **Emerging risk:** Indication of prediabetes
2. **At risk:** T2D diagnosis, with no factors from “Severe” T2D category
3. **Severe:** T2D with severe complication(s), for example T2D related to admission, ER visit, and renal complications

Descriptive analytics

Upon integrating the clinical, behavioral and SDOH dataset, we sought to broadly understand this population from a cost, utilization and SDOH perspective through descriptive analytics. Figure 3 shows two sample tables from an overall Tableau dashboard that was created to visually display the SDOH characteristics of the population across the T2D progression spectrum.

The table first below shows the population’s distribution and likelihood to experience SDOH insecurities on a scale from ‘very low’ to ‘very high’ likelihood. It shows that more than half of members are experiencing ‘high’ or ‘very high levels’ of social isolation, transportation insecurity, and financial insecurity. The second table depicts SDOH burden broken down by disease stage. This view helps to focus on which individual members are the most vulnerable. The second graph shows that as disease progresses, the share of members with two or more SDOH factors with ‘high’ or ‘very high’ insecurity increases. Similarly, as disease progressed the share of members with no SDOH factors decreased.

	Food insecurity	Social isolation	Housing insecurity	Transportation insecurity	Financial insecurity
Very high	27.0%	35.0%	15.3%	52.0%	33.6%
High	5.9%	16.8%	8.1%	10.2%	17.2%
Moderate	8.2%	19.9%	16.7%	19.1%	18.9%
Low	17.3%	16.2%	28.5%	12.5%	16.4%
Very low	41.6%	12.2%	31.4%	6.2%	14.0%
Grand total	100.0%	100.0%	100.0%	100.0%	100.0%

	SDOH count					
	0	1	2	3	4	5
Advanced	25.9%	26.8%	18.7%	11.9%	9.5%	7.2%
At risk	28.6%	27.8%	17.9%	10.6%	8.2%	6.9%
Stable	28.1%	25.9%	17.5%	11.1%	9.2%	8.3%
Emerging	27.8%	27.1%	17.6%	10.4%	8.8%	8.3%
Prediabetes	31.6%	28.8%	16.8%	8.9%	7.2%	6.6%
No RF	17.0%	22.2%	16.8%	11.8%	14.4%	17.8%
Grand total	19.7%	23.4%	17.0%	11.4%	13.0%	15.5%

Figure 3: Sample Tableau dashboard, filtered to show all lines of business and diabetes condition levels. SDOH count is in regard to the number of members with high or very high security issues in one of the five SDOH categories

Figure 4 shows the size of the population by line of business and T2D progression within the analysis. The population characteristics resembled what would be expected in the general population. Approximately 13% of the membership had a T2D diagnosis, with the Medicare and Dual populations having 2.5 times to 3 times the rate of the overall population.

Line of business	Total population	No T2D	T2D	T2D condition levels under analysis			
				Emerging risks	Non-severe	Severe	% of total T2D
Medicare	312,951	210,448	102,503	40,815	33,946	27,742	34%
Medicaid	406,260	376,896	29,364	9,664	10,812	8,888	10%
Commercial	1,545,259	1,380,146	165,113	86,841	52,566	25,706	54%
Dual eligible	12,368	7,359	5,009	930	1,669	2,410	2%
Total	2,276,838	1,974,849	301,989	138,250	98,993	64,746	100%
% of total	100%	87%	13%	6%	4%	3%	

Figure 4: Population size under analysis. Dual Eligible are members who qualify for both Medicaid and Medicare.

Diagnostic analytics

The purpose of the diagnostic analysis was to determine the significant predictors of T2D incidence and severity levels from the available demographic, SDOH, behavioral, and clinical data. The methodology leveraged prepared a member level dataset with demographic details, SDOH indicators, lifestyle factors and T2D incidence and severity levels. Then, inter-relationships among them were identified and their impact on T2D severity levels were analyzed through decision trees.

We used logistical regression modeling to show the comparative importance of different SDOH factors on incidence and progression of T2D, across four lines of business. Figure 5 shows the most important SDOH and non-clinical factors for the overall incidence of T2D across lines of business. Unlike the clinical factors, there were differences across lines of business and SDOH factors. Among the Medicare population, the most important factors were midstream factors like financial insecurity, transportation insecurity and social isolation. The most important factors for commercial and Medicaid were level of engagement (HOI, or health ownership index), and the most important for dual eligible were around ethnicity, language and security factors.

Commercial	Medicaid	Medicare	DSNP
HOI — Low health status	HOI — Low health status	Financial insecurity	Ethnicity
Socio-economic status	HOI — Low health ownership	Socio-economic status	Language code
HOI — Low health ownership	Socio-economic status	Transportation insecurity	HOI — Low health status
Propensity to engage	Propensity to engage — IB	Housing insecurity	Socio-economic status
Propensity to engage — CM	Propensity to engage	Social isolation	Financial insecurity
Propensity to engage — IB	Language	Food insecurity	Housing insecurity
Language code	Ethnicity	Ethnicity	HOI — Low health ownership
Housing insecurity	Housing insecurity	HOI — Low health status	Transportation insecurity
Ethnicity	Propensity to engage — CM	Language	Food insecurity
Food insecurity	Food insecurity	HOI — Low health ownership	Propensity to engage — CM
Financial insecurity	Financial insecurity	Propensity to engage	Social isolation
Transportation insecurity	Social isolation	Propensity to engage — IB	Propensity to engage
Social isolation	Transportation insecurity	Propensity to engage — CM	Propensity to engage — IB

Comparative scale against median
Strong prediction
Medium prediction
Negative prediction

Figure 5: Top five non-clinical factors for T2D incidence by line of business

Figure 6 shows the relationship between the most important non-clinical factors and T2D severity. A couple of items stand out. First, SDOH security issues stand out across the board regardless of the line of business. Among the most important SDOH security issues were financial, housing and transportation. Second, SDOH factors varied significantly across lines of business, unlike previous analysis. Similarly, sensitivity to non-clinical factors varied by line of business, with Dual Eligible and Medicare being the most sensitive. While it appeared Medicaid had the least sensitivity to non-clinical factors, this data is likely artificially suppressed due to lack of access and low reimbursement. Lastly, there was significant impact of SDOH factors on incidence and severity among the commercial population, contrary to mainstream assumptions that SDOH factors are only significant for elderly and low-income members.

Commercial	Medicaid	Medicare	DSNP
Socio-economic status	HOI — Low health status	Financial insecurity	Financial insecurity
HOI — Low health status	Housing insecurity	Transportation insecurity	HOI — Low health status
Housing insecurity	HOI — Low health ownership	Socio-economic status	Housing insecurity
Financial insecurity	Propensity to engage	Housing insecurity	Propensity to engage — IB
Social isolation	Socio-economic status	Social isolation	Transportation insecurity
Food insecurity	Propensity to engage — CM	Food insecurity	Socio-economic status
Propensity to engage	Ethnicity	Ethnicity	Social isolation
Propensity to engage — CM	Food insecurity	Language	Ethnicity
Language code	Financial insecurity	HOI — Low health status	HOI — Low health ownership
Ethnicity	Transportation insecurity	HOI — Low health ownership	Propensity to engage
Propensity to engage — IB	Social isolation	Propensity to engage	Food insecurity
HOI — Low health ownership	Propensity to engage — IB	Propensity to engage — IB	Language code
Transportation insecurity	Language	Propensity to engage — CM	Propensity to engage — CM

Comparative scale against median
Strong prediction
Medium prediction
Negative prediction

Figure 6: Top five non-clinical factors for T2D severity by line of business

Overall, the diagnostic modeling work showed that there are similarities in underlying clinical and non-clinical factors and T2D incidence in general; however, that did not hold true in regard to severity of T2D and progression. While there were diagnostic factors consistent across lines of business, there were unique factors as well that can be leveraged to create line of business specific, actionable decision trees.

Predictive and prescriptive analytics

T2D progression by SDOH factors — R2 analysis

Medicaid		
Diabetic	Emerging	No diabetes
HOI — Low health status	Transportation insecurity	Transportation insecurity
Transportation insecurity	HOI — Low health status	SDOH count
Financial insecurity	SDOH count	HOI — Low health status
HOI — Low health ownership	HOI — Low health ownership	HOI — Low health ownership
SDOH count	Food insecurity	Financial insecurity
Food insecurity	Financial insecurity	Food insecurity
Social isolation	Social isolation	Socio-economic status
Socio-economic status	Socio-economic status	Social isolation
Propensity to engage — IB	Housing insecurity	Housing insecurity
Housing insecurity	Language	Propensity to engage — CM
Language	Propensity to engage — IB	Propensity to engage
Propensity to engage — CM	Propensity to engage — CM	Language
Ethnicity	Ethnicity	Ethnicity
Propensity to engage	Propensity to engage	Propensity to engage — IB

Comparative scale against median **Strong prediction** Medium Negative

Figure 7 shows the SDOH factors with the largest impact on T2D progression among the Medicaid population. For Medicaid members, HOI — low health status, transportation insecurity, HOI — low health ownership showed better prediction strength in comparison to other SDOH factors at all condition level of T2D. Additionally, socio-economic status was a stronger predictor in T2D severity level compared to language and ethnicity.

Figure 7: SDOH factors vs. T2D progression

Commercial		
Diabetic	Emerging	No diabetes
HOI — Low health status	HOI — Low health status	HOI — Low health status
Transportation insecurity	Social isolation	Transportation insecurity
Social isolation	SDOH count	SDOH count
SDOH count	HOI — Low health ownership	Social isolation
Language	Transportation insecurity	Financial insecurity
Financial insecurity	Financial insecurity	HOI — Low health ownership
HOI — Low health ownership	Food insecurity	Food insecurity
Propensity to engage	Housing insecurity	Housing insecurity
Ethnicity	Ethnicity	Socio-economic status
Food Insecurity	Propensity to engage — CM	Propensity to engage
Propensity to engage — CM	Socio-economic status	Language
Housing insecurity	Propensity to engage	Ethnicity
Socio-economic status	Language	Propensity to engage — CM
Propensity to engage — IB	Propensity to engage — IB	Propensity to engage — IB

Comparative scale against median **Strong prediction** Medium Negative

Figure 8 shows the SDOH factors with the largest impact on T2D progression among the commercial population. For commercial members, health ownership — low health status was the strongest among all SDOH factors at all condition levels. Additionally, propensity to engage — IB (inbound call) and propensity to engage — CM (care management) showed an inverse relation in determining the T2D condition level.

Figure 8: SDOH factors vs. T2D progression

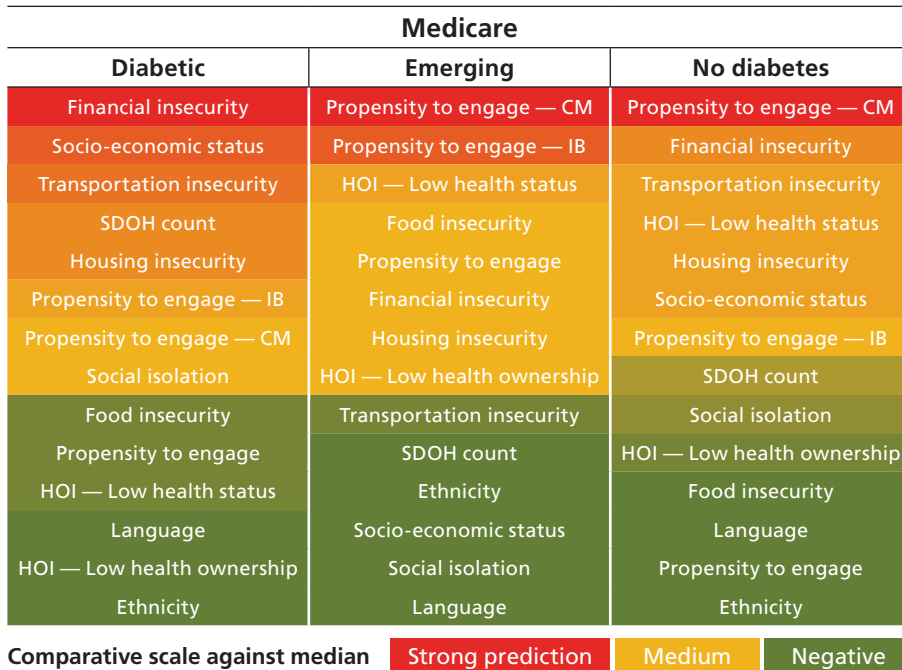


Figure 9 shows the SDOH factors with the largest impact on T2D progression among the Medicare population. For Medicare members, propensity to engage — CM (likelihood for someone to engage in care and disease management programs) showed comparatively better relationship in determining the early stage of T2D. Additionally, socio-economic status showed a good relationship in predicting T2D at the advanced level.

Figure 9: SDOH factors vs. T2D progression

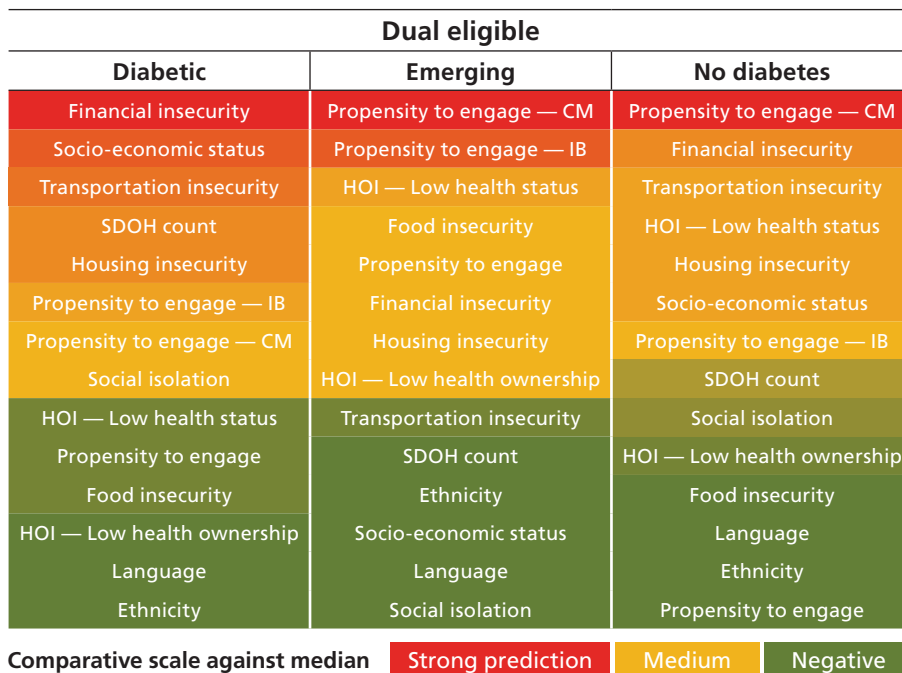


Figure 10 shows the SDOH factors with the largest impact on T2D progression among the DSNP population. For DSNP members, financial insecurity and transportation insecurity emerged as the strongest SDOH factors among all for the Severe T2D condition level. Language and ethnicity showed an inverse relation in determining the T2D condition level at all stages.

Figure 10: SDOH factors vs. T2D progression

In the next part of the analysis, decision tree modeling was used to identify the individuals most likely to progress from prediabetes/T2D to complex T2D and the most important factors for that progression. Trees were constructed using SDOH and clinical data, but SDOH factors were not the most significant predictors of progression.

Figure 11 shows an example of the decision tree analysis for the Medicaid population. The same model was developed for all lines of business. In this case, the decision points for 30,000 members along the continuum were funneled down to the ones most likely to end up with severe T2D. Starting at the top, the cost threshold was the most important. After that, it was whether someone was already diagnosed with hypertension, followed by hyperlipidemia. Overall, approximately 4,700 members (~16%) were identified to be most likely to become severe diabetics.

The power of this analysis comes from knowing the detailed SDOH and clinical characteristics of the 4,700 members who are likely to progress from prediabetes/T2D to severe T2D. Their underlying comorbidities are known, as well as their risk characteristics, SDOH characteristics, barriers to care and their motivators via level of engagement and health ownership.

By having this person level information for a very targeted population, particular needs can be addressed, and programs tailored to account for barriers and motivators, thus allowing members to be connected to the appropriate clinical and social resources. This will ultimately result in more effective and efficient systems of care.

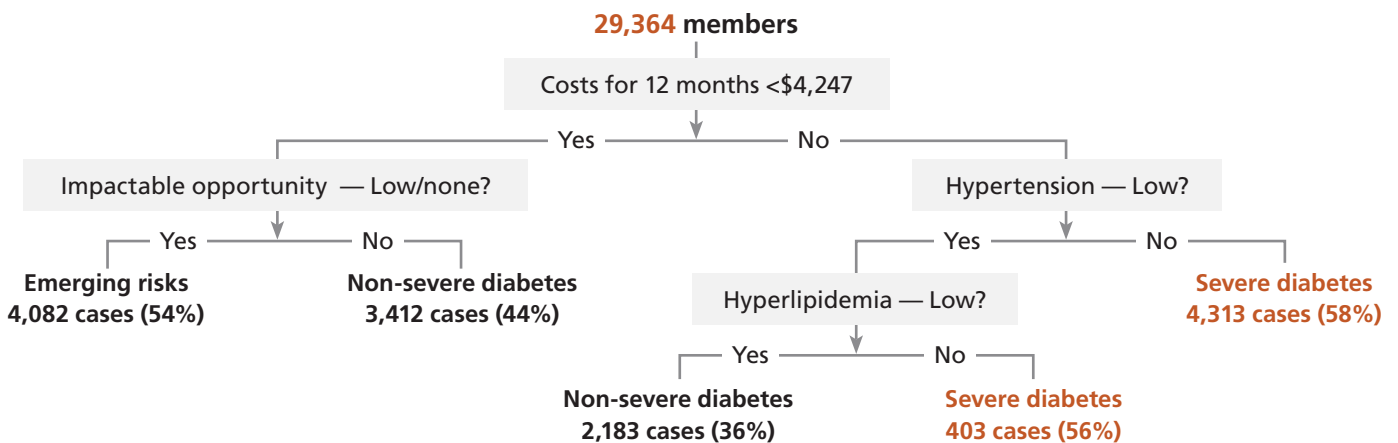


Figure 11: Sample decision tree output — Medicaid (prediabetes and T2D progression to severe T2D)

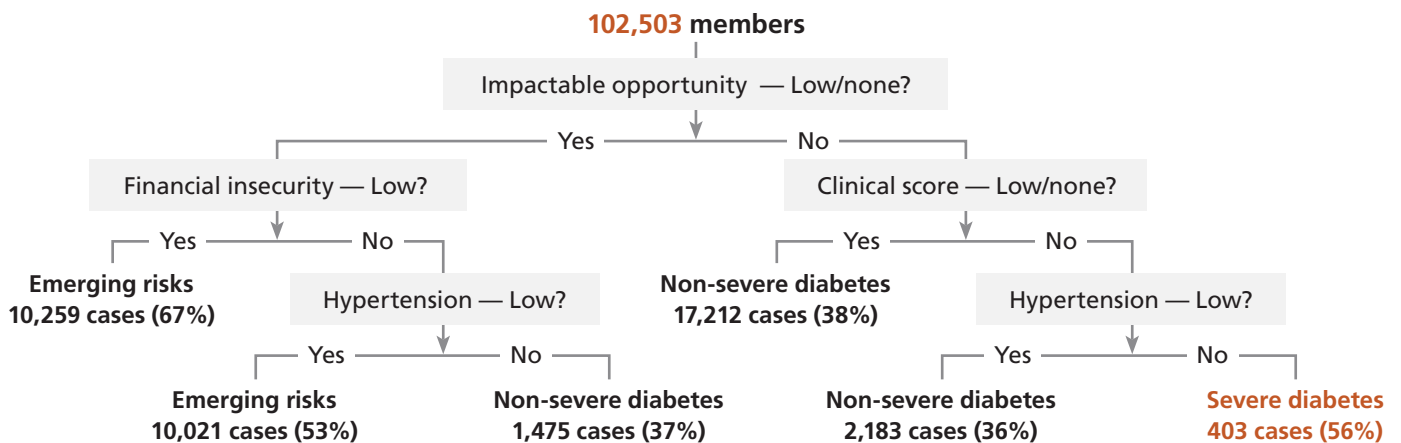


Figure 12: Sample decision tree output — Medicare (prediabetes and T2D progression to severe T2D)

Custom Impact Pro (IPro) reports

IPro is an Optum prospective analytics tool that leverages whole person data and analytics to identify future risk and cost at the person level. The results from the decision tree analysis provided the statistically significant predictors and cut-points to identify members who are likely to progress from prediabetic/T2D to severe T2D which enabled custom Impact Pro reports to be created to flag members on a monthly basis who meet the identified at risk criteria. Impact Pro is a member-centered analytic platform that helps to identify individuals who need specialized intervention programs by assessing cost, risk and impact.

Since the decision tree analyses were conducted at the line of business level, four flags were created so care teams can easily identify individuals who are at risk and engage them in outreach or care management programs. Impact Pro easily brings into view the identified individual's clinical, SDOH, utilization and behavioral data which allows for targeted intervention strategies.

Conclusion

For this analysis, we used the Robert Wood Johnson Foundation (RWJ) on SDOH which connects upstream factors (such as race and language) to midstream outcomes (such as housing and food security) to downstream health outcomes (such as the incidence and progression of T2D). This work presents a novel framework that allows for better understanding and more impactful upstream interventions to address social determinants at the individual level before disease becomes severe, leading to altered outcomes. In practice, this framework offers an actionable tool for applied health equity work at the individual and population level.

These results showed the importance of SDOH, clinical, and non-clinical factors across different populations based on the line of business and along T2D progression. There were differences in the underlying factors along T2D progression across lines of business, but also significant consistencies in relation to onset of T2D. SDOH factors were not seen to have as important of an impact on progression across line of business, though they were impactful in relation to onset and severity. Though there was not a correlation between SDOH factors and disease progression in the Medicaid population, this is likely due to artificial data suppression from lack of access and low reimbursement rates.

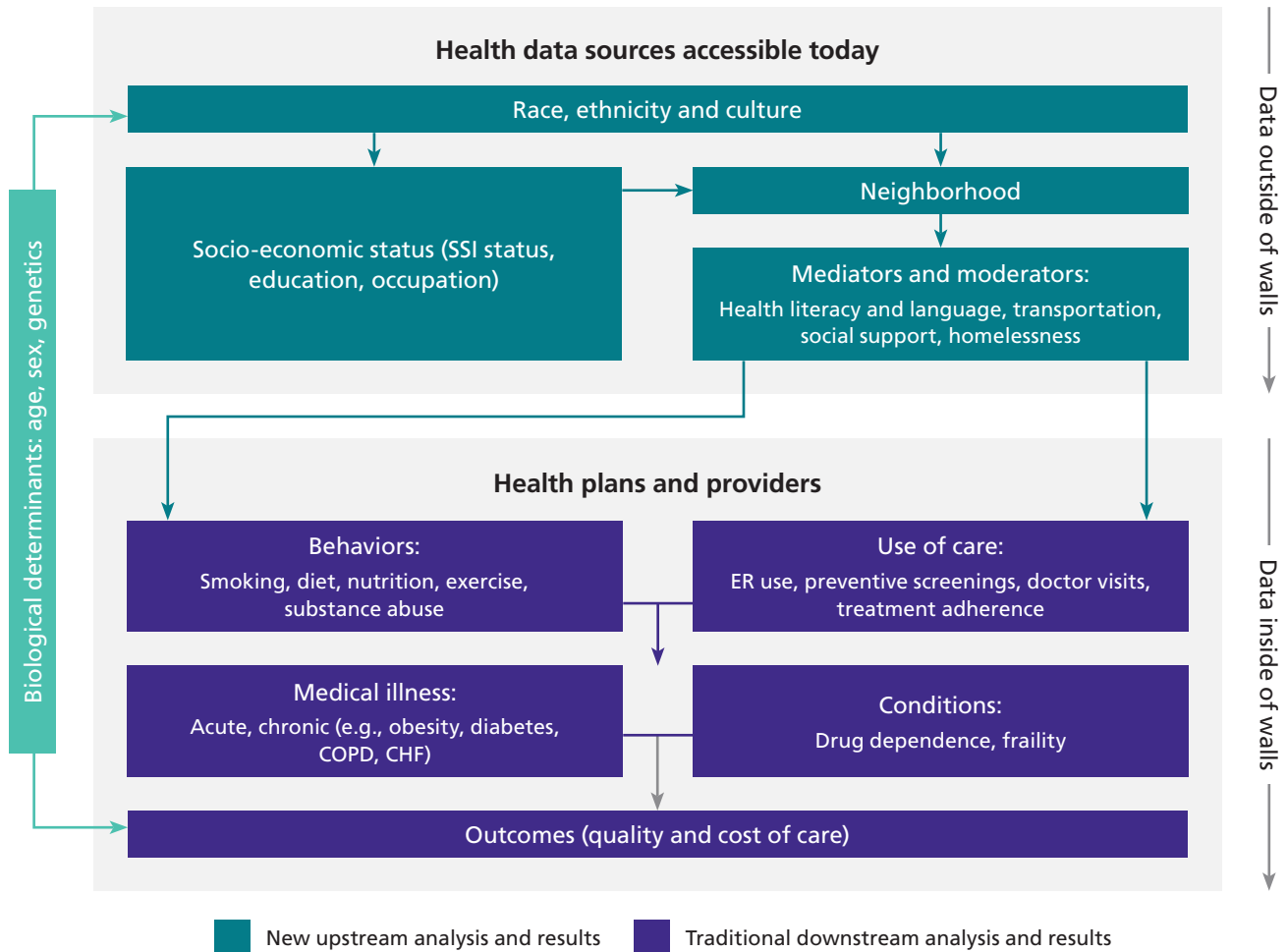


Figure 13: SDOH framework

This model and analytical framework provides a whole person view of an individual in a quantitative way, moving backwards from outcomes to upstream predictors. The variations identified across lines of business suggest successful interventions to reduce T2D incidence will look different for each line of business. For Dual Eligible, the focus would be on culturally tailored interventions that incorporate tools to address SES and financial security. Interventions for Medicare would address transportation insecurity and common SDOH factors. Medicaid interventions might focus on programing to coach and address ownership and engagement while focusing on improving SES. Commercial interventions would focus on addressing SES, as well as health ownership and engagement. Thus, characterizing these differences across lines of business allows for tailored program design and interventions that are data driven. Future work could be done to further isolate SDOH factors through decision tree analysis, as well as to explore how SDOH factors and degree of burden affect the rate of progression and onset. Our analysis focused on T2D, but this framework could be used for any disease, with the result being improved care management, reduced disparities and better outcomes.

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