Longitudinal Analysis of Diabetes Progression in Medicare Patients Using Claims Data

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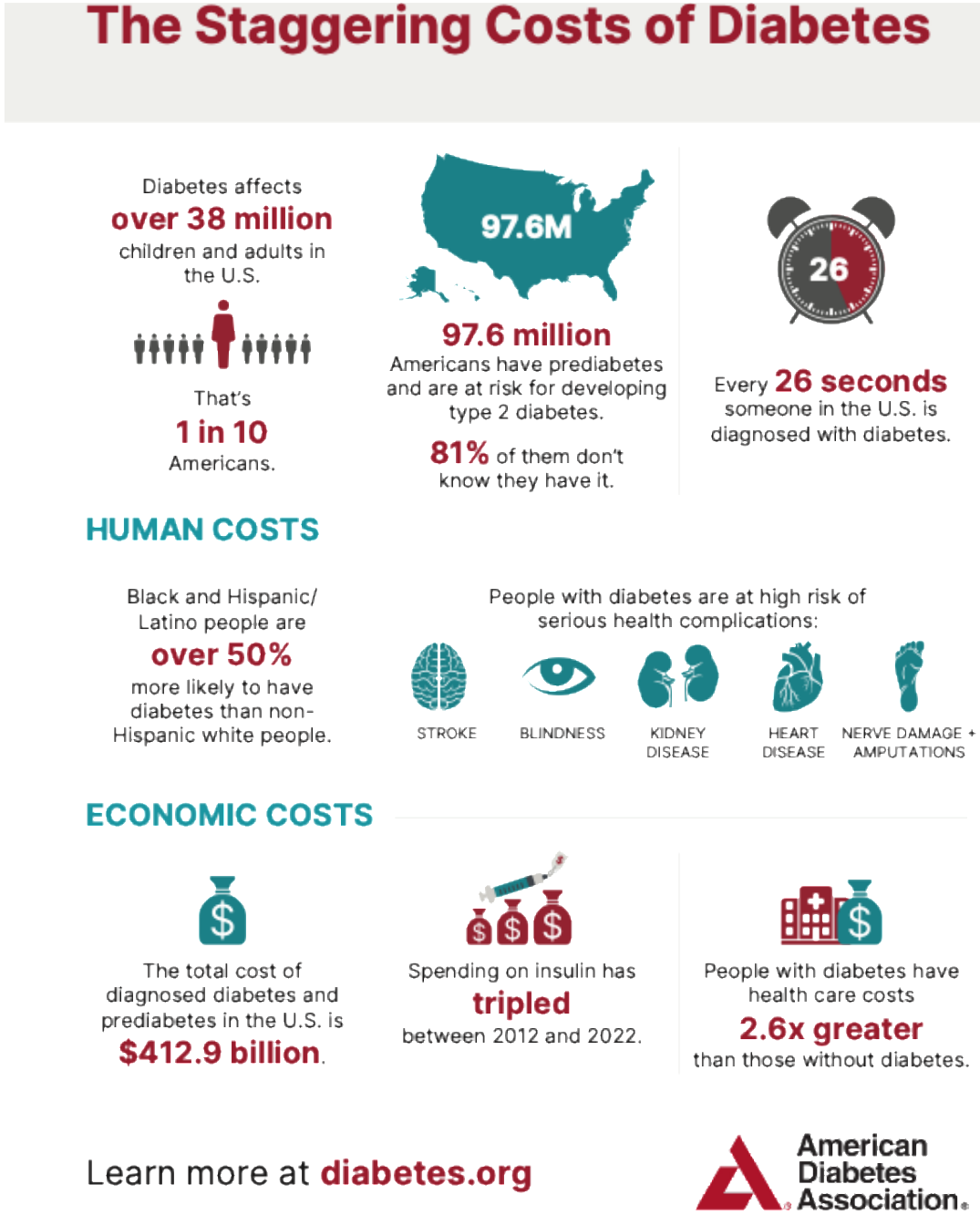
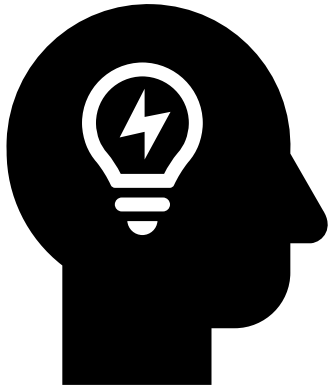


https://diabetes.org/sites/default/files/2024-09/ADA_2024_StaggeringCostsOfDiabetes.pdf



- How can we intervene? What policies can be implemented?
- What factors drive diabetes progression?
- How likely could one develop complications from diabetes?

This project…

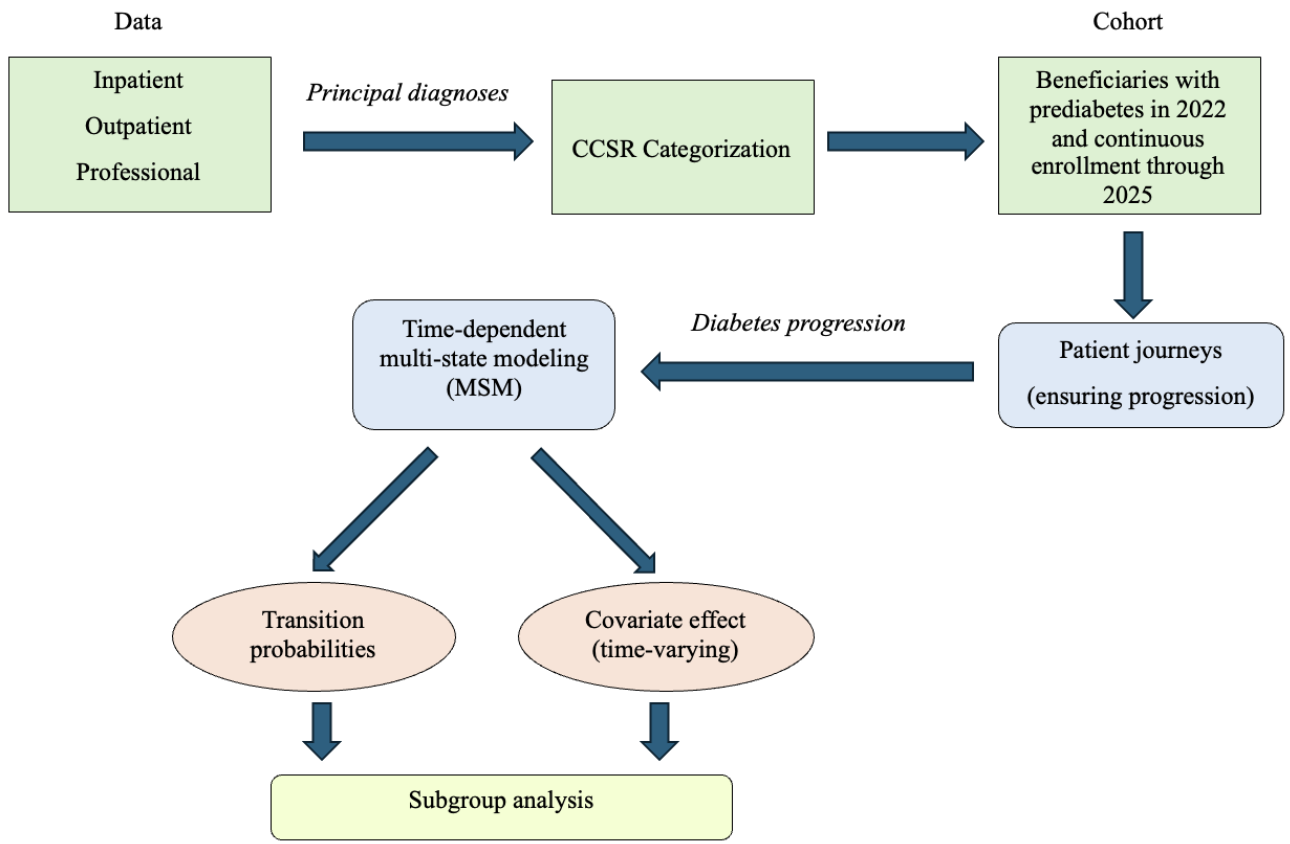
explores some efficient ways of handling electronic health records – from data ingestion to analyses

examines the longitudinal paths of diabetes progression among Medicare beneficiaries

Methods

Study Design

- Longitudinal
- Medicare beneficiaries followed from time of prediabetes
- Synthetic data from CMS (inpatient, outpatient, professional)



Patients' Diagnoses

– Principal diagnosis (underlying cause of admission)

– Re-categorized using CCSR

– Considered first time a condition was diagnosed

Cohort and Progression

– Beneficiaries diagnosed with prediabetes in 2022, with continuous enrollment (*n*=3,172)

– Includes only patients who "progressed"

– Excludes patients with more than one distinct diabetes diagnoses at any time

Covariates

– Demographics: age, sex, race (time-independent)

– Comorbidities: obesity, hypertension, heart disease or failure, socioeconomic or lifestyle factors, alcohol-related disorders, depressive or anxiety disorders, sleep wake disorders (time-dependent)

Time to Progression

– Synthetic patient journeys (random months January-December)

– Time (months) = time diagnosed – time of prediabetes

– Censoring attributable to end of follow-up period

Statistical Analyses

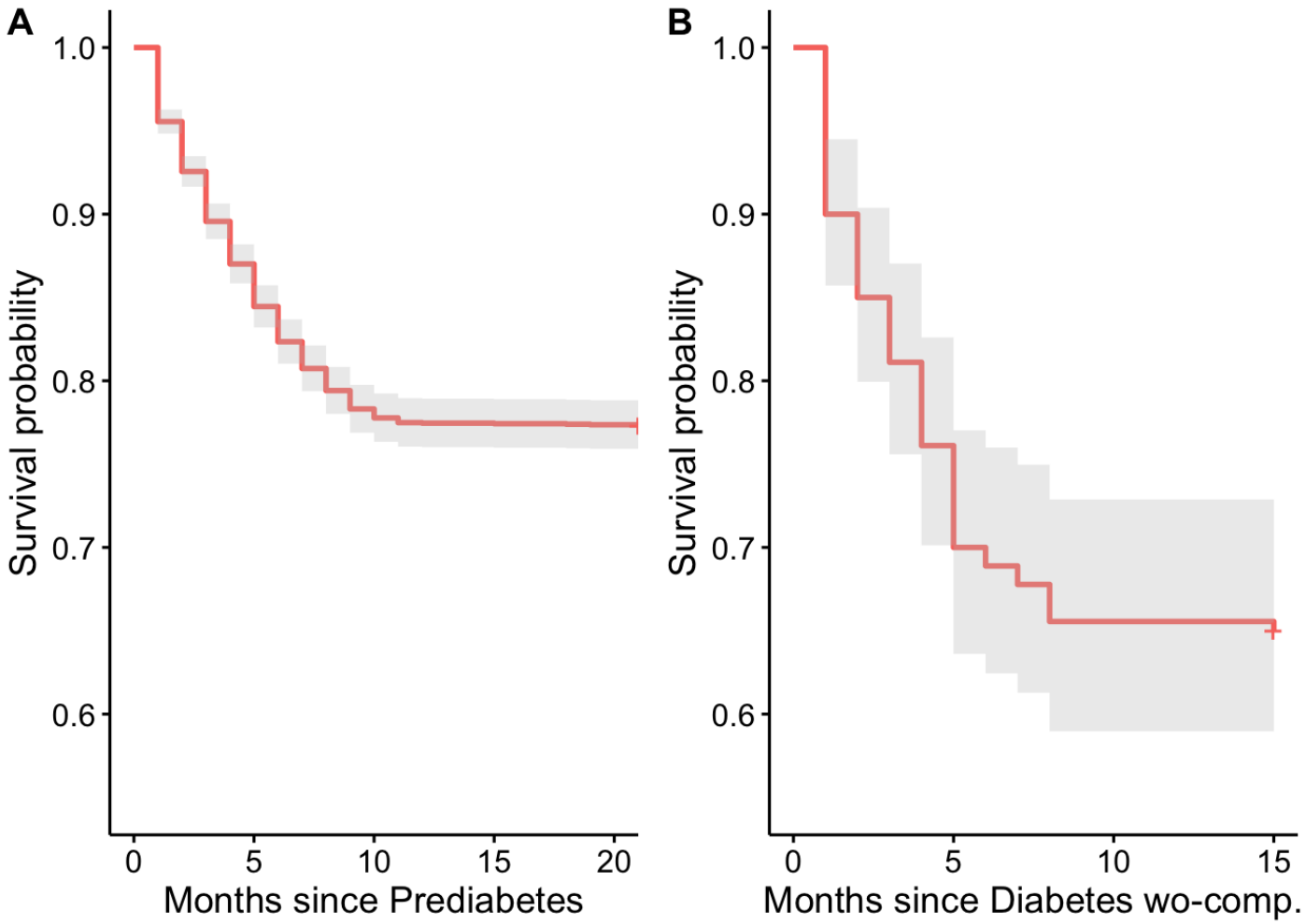
- Progression-free survival probability
  - Non-parametric Kaplan-Meier survival estimator

- Transition Probability
  - Continuous-time multi-state models (MSM)
  - Plausible transitions: 1→2, 1→3, or 2→3
  - 1: prediabetes, 2: diabetes mellitus without complications, 3: diabetes mellitus with complications

- Models adjusted for demographics and comorbidities

Results

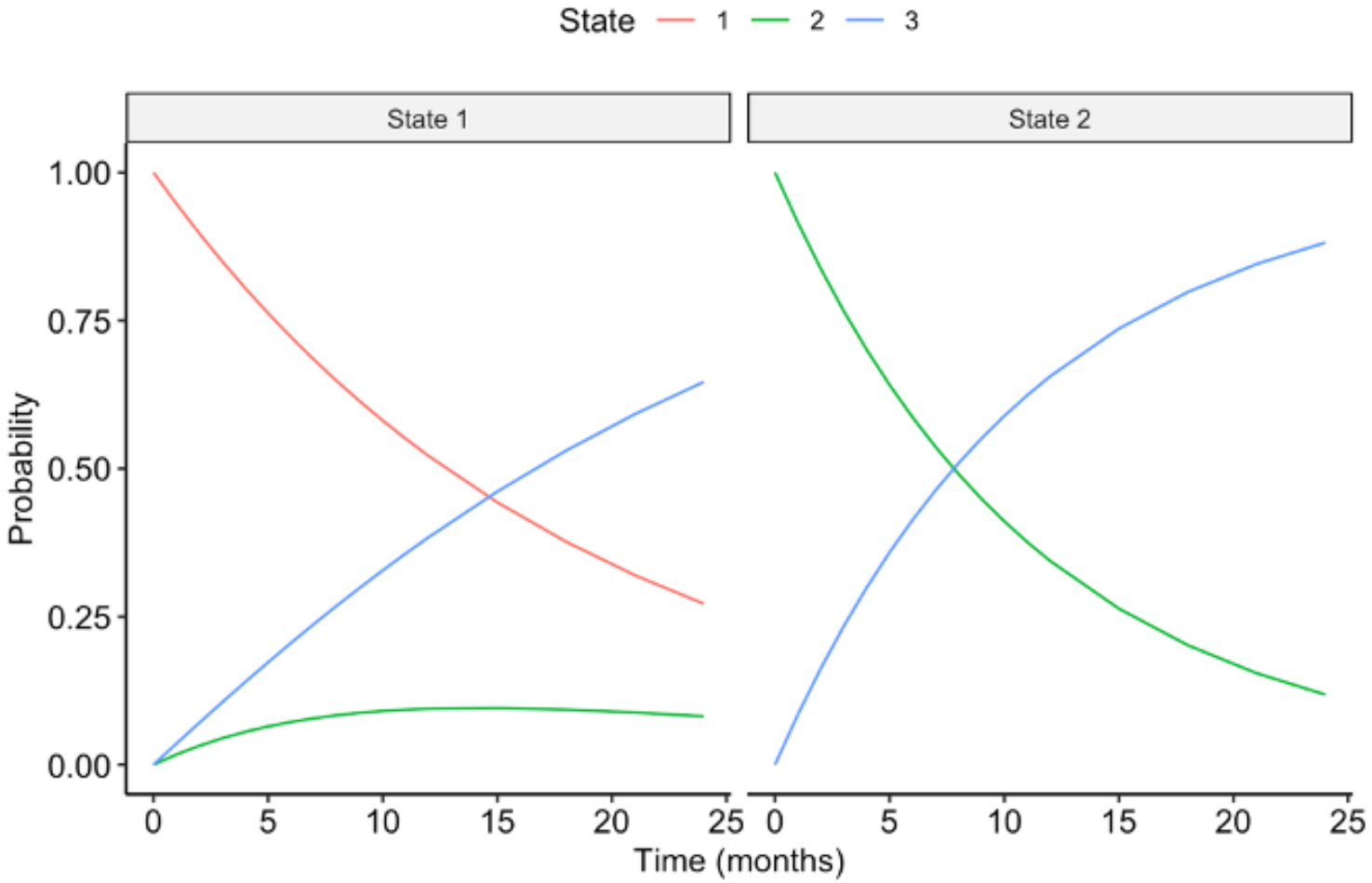
Progression-free Survival



Survival probability curves for diabetes progression.

- **(A)** Progression from prediabetes
- **(B)** Progression from diabetes without complications
- Delayed progression from state=1 than from state=2

Transition Probability



Transition probabilities over time

- **Left**: Probability of transitioning given state 1
- **Right**: Probability of transitioning given state 2
- Probability of remaining in current state decreases
- More likely for 2→3 than 1→3
- More likely for 1→3 than 2→3

Factors affecting Diabetes progression

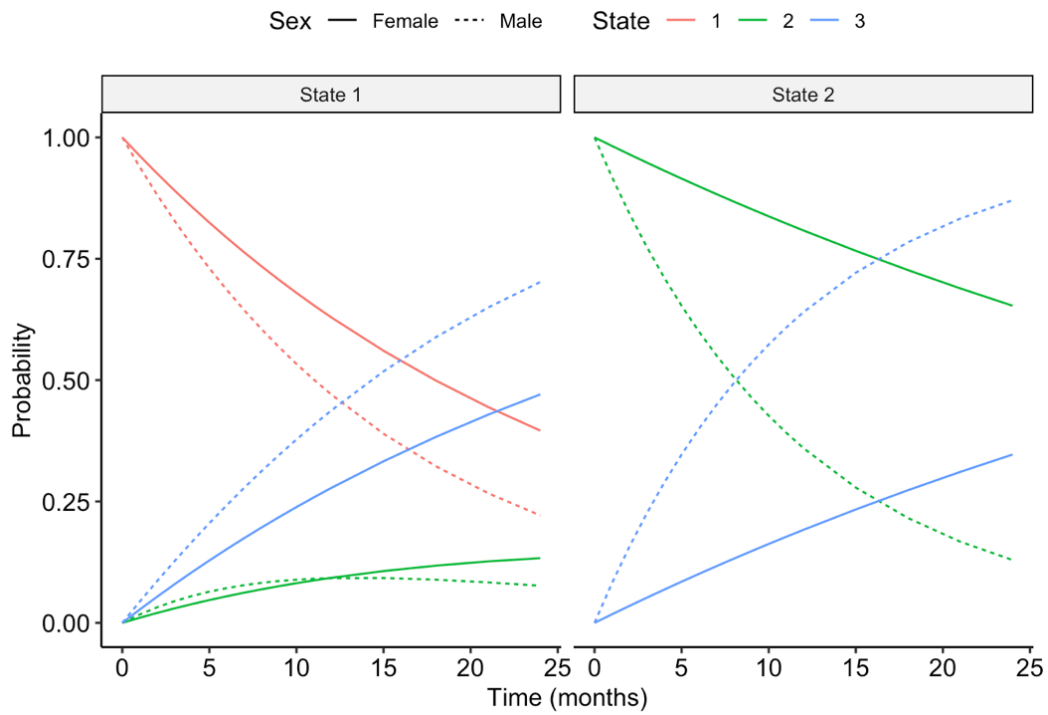
Covariate	1-2*	1-3*	2-3*
Obesity	1.288 (0.949, 1.747)	**1.663 (1.379, 2.006)**	1.412 (0.827, 2.41)
Socioeconomic or lifestyle factors	**1.366 (1.006, 1.854)**	**2.239 (1.835, 2.733)**	1.396 (0.805, 2.422)
Hypertension	**2 (1.449, 2.761)**	**4.808 (3.968, 5.825)**	**1.962 (1.136, 3.388)**
Heart disease or failure	**1.993 (1.435, 2.769)**	**1.497 (1.213, 1.848)**	1.588 (0.918, 2.747)
Sleep wake disorders	0.525 (0.273, 1.008)	0.957 (0.717, 1.279)	0.507 (0.206, 1.247)
Alcohol-related disorders	1.325 (0.502, 3.495)	1.382 (0.853, 2.238)	2.171 (0.423, 11.134)
Depressive or anxiety disorders	1.71 (0.765, 3.824)	**2.185 (1.469, 3.249)**	1.849 (0.58, 5.894)
Sex	1.015 (0.749, 1.375)	0.797 (0.658, 0.965)	0.802 (0.471, 1.364)
Race	1.002 (0.91, 1.102)	1.02 (0.963, 1.082)	1.078 (0.916, 1.269)
Age (years)	**1.014 (1.002, 1.026)**	1.003 (0.996, 1.011)	**1.044 (1.02, 1.068)**

* 1 = Prediabetes, 2 = Diabetes mellitus without complication, 3 = Diabetes mellitus with complication.

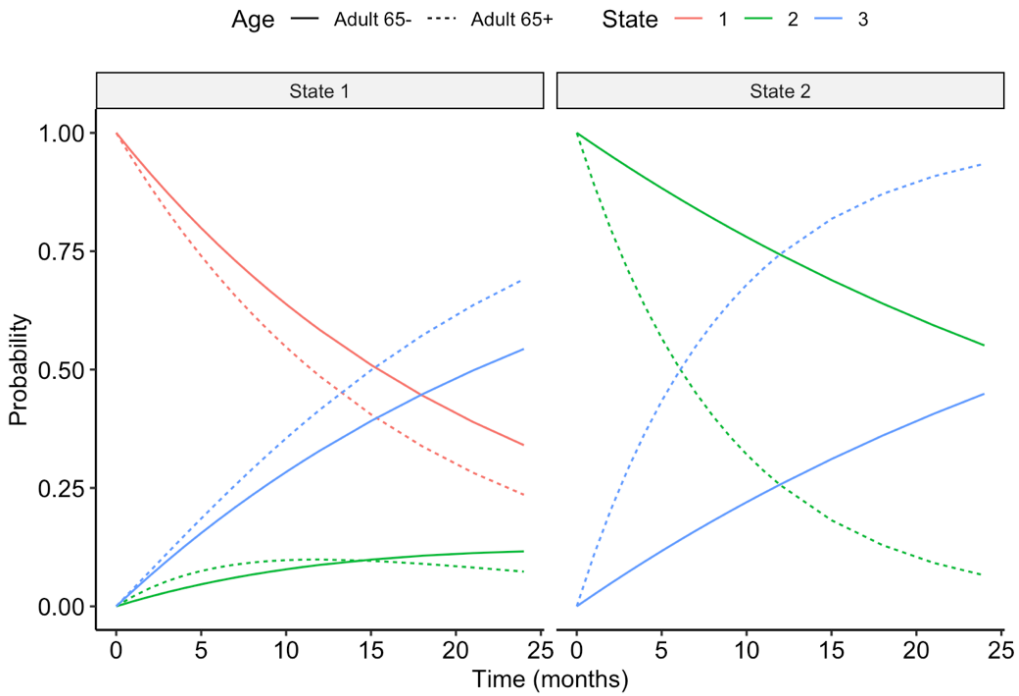
Estimated hazard ratios for different transitions

Age- and Sex- stratified Subgroup Analyses

Transition Probability Curves



Sex



Age

Age- and Sex- stratified Subgroup Analyses

Estimated hazard ratios (SEX)

Covariate	Males			Females		
	1-2	1-3	2-3	1-2	1-3	2-3
Obesity	1.216 (0.794, 1.862)	**1.527 (1.193, 1.954)**	0.931 (0.46, 1.883)	1.432 (0.93, 2.203)	**1.845 (1.376, 2.473)**	**2.876 (1.185, 6.979)**
Socioeconomic or lifestyle factors	**1.618 (1.049, 2.495)**	**2.203 (1.698, 2.859)**	1.459 (0.695, 3.065)	1.274 (0.828, 1.962)	**2.19 (1.606, 2.988)**	1.869 (0.811, 4.308)
Hypertension	**2.051 (1.299, 3.24)**	**4.225 (3.284, 5.436)**	**2.762 (1.29, 5.914)**	**2.142 (1.356, 3.384)**	**5.84 (4.328, 7.88)**	1.787 (0.783, 4.079)
Heart disease or failure	**2.372 (1.5, 3.75)**	**1.46 (1.116, 1.908)**	**3.268 (1.466, 7.284)**	**1.827 (1.147, 2.911)**	**1.443 (1.01, 2.062)**	1.166 (0.525, 2.593)
Sleep wake disorders	0.587 (0.267, 1.289)	1.065 (0.75, 1.513)	0.719 (0.288, 1.8)	0.41 (0.128, 1.317)	0.758 (0.443, 1.298)	0 (0, Inf)
Alcohol-related disorders	**3.054 (1.157, 8.066)**	1.056 (0.411, 2.715)	**4.799 (1.124, 20.499)**	0 (0, Inf)	1.505 (0.736, 3.081)	0 (0, Inf)
Depressive or anxiety disorders	2.328 (0.834, 6.497)	**2.794 (1.657, 4.712)**	1.758 (0.534, 5.781)	1.157 (0.312, 4.284)	1.733 (0.946, 3.175)	0.946 (0.079, 11.373)
Race	1.077 (0.947, 1.226)	0.983 (0.906, 1.066)	1.084 (0.884, 1.329)	0.941 (0.815, 1.086)	1.061 (0.973, 1.157)	1.259 (0.966, 1.641)
Age (years)	1.005 (0.987, 1.023)	1.005 (0.995, 1.015)	1.025 (0.992, 1.059)	**1.02 (1.005, 1.036)**	1.003 (0.992, 1.014)	**1.069 (1.035, 1.103)**

1 = Prediabetes, 2 = Diabetes mellitus without complication, 3 = Diabetes mellitus with complication.

Age- and Sex- stratified Subgroup Analyses

Estimated hazard ratios (AGE)

Covariate	Adults <65			Adults 65+		
	1-2	1-3	2-3	1-2	1-3	2-3
Obesity	1.399 (0.752, 2.6)	**1.599 (1.18, 2.168)**	1.929 (0.343, 10.855)	1.207 (0.845, 1.723)	**1.752 (1.378, 2.229)**	1.175 (0.671, 2.058)
Socioeconomic or lifestyle factors	**2.065 (1.097, 3.889)**	**2.541 (1.851, 3.489)**	0.514 (0.089, 2.979)	1.234 (0.866, 1.758)	**2.073 (1.612, 2.666)**	1.639 (0.884, 3.04)
Hypertension	1.693 (0.848, 3.378)	**5.177 (3.818, 7.02)**	**5.36 (1.239, 23.194)**	**2.213 (1.528, 3.206)**	**4.489 (3.525, 5.717)**	**2.347 (1.291, 4.268)**
Heart disease or failure	1.536 (0.505, 4.675)	**1.71 (1.061, 2.757)**	**7.056 (1.482, 33.594)**	**2.087 (1.474, 2.955)**	**1.639 (1.294, 2.076)**	1.733 (0.969, 3.1)
Sleep wake disorders	0.529 (0.205, 1.365)	0.723 (0.48, 1.089)	0.566 (0.095, 3.382)	0.555 (0.222, 1.387)	1.162 (0.771, 1.752)	0.397 (0.119, 1.327)
Alcohol-related disorders	1.314 (0.315, 5.486)	1.364 (0.664, 2.801)	0 (0, Inf)	1.445 (0.358, 5.842)	1.292 (0.616, 2.712)	3.001 (0.513, 17.562)
Depressive or anxiety disorders	2.079 (0.634, 6.823)	**1.848 (1.009, 3.386)**	1.275 (0.096, 17.013)	1.392 (0.474, 4.087)	**2.448 (1.482, 4.043)**	2.226 (0.623, 7.954)
Sex	0.642 (0.346, 1.194)	0.82 (0.603, 1.115)	0.273 (0.035, 2.156)	1.129 (0.794, 1.605)	0.798 (0.624, 1.019)	0.806 (0.447, 1.455)
Race	1.068 (0.872, 1.309)	1.039 (0.941, 1.148)	1.526 (0.982, 2.372)	0.983 (0.88, 1.098)	1.016 (0.945, 1.092)	0.981 (0.806, 1.193)

1 = Prediabetes, 2 = Diabetes mellitus without complication, 3 = Diabetes mellitus with complication.

Conclusion

- Most prediabetic patients develop diabetes with complications without being diagnosed of diabetes without complications
- Obesity, hypertension, and heart disease/failure are some of the factors that significantly impact diabetes progression
- Males and older adults have higher chances of progression than females and younger adults
- Future work could:
  - Incorporate real Medicare claims data for generalizability
  - Incorporate medication use (e.g., antidiabetics)


Thank you