



# Machine Learning Evaluation of Racial and Ethnic Inclusion under Alternative Cost-Based Approaches to Medicare Medication Therapy Management Eligibility

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## BACKGROUND

- The Medicare Part D Medication Therapy Management (MTM) program targets high-need beneficiaries, but its eligibility criteria have been linked to lower inclusion of racial/ethnic minority groups.<sup>1,2</sup>
- The Enhanced MTM demonstration expanded plan flexibility in identifying eligible beneficiaries, with participating Part D plans adopting predictive modeling that may perpetuate underlying racial/ethnic inequities.<sup>3</sup>
- Limited evidence exists on how cost components, including commonly used total healthcare costs,<sup>3</sup> influence racial/ethnic inclusion in MTM eligibility.

## OBJECTIVES

To assess racial/ethnic differences in predicted inclusion under two cost-based schemes: total healthcare and hospitalization/emergency room (ER) costs.

## METHODS

- Study design:** A cross-sectional analysis of 2019 Medicare administrative data and the Area Health Resources Files using a policy-scenario approach.
- Study sample:** A 10% random sample of 2019 Medicare fee-for-service beneficiaries, restricted to those alive at the end of the year and with continuous Parts A, B, and D enrollment.
- Conceptual framework:** Gelberg-Anderson behavioral model for vulnerable populations.<sup>4</sup>
- Outcome:** A four-level categorical measure representing joint inclusion across two cost-based schemes, based on predicted top-quartile inclusion for total healthcare costs and combined hospitalization/ER costs.
  - Top-quartile threshold reflects Centers for Medicare and Medicaid Services expectations that 25% of beneficiaries may qualify for MTM eligibility.<sup>5</sup>
  - Total healthcare costs were computed from Medicare Parts A, B, and D claims; hospitalization costs were derived from inpatient claims; ER costs were identified using revenue center codes (0450–0459, 0981).<sup>6</sup>
  - Four-level categorical outcome: predicted inclusion in neither scheme (category 1), total healthcare scheme only (category 2), hospitalization/ER scheme only (category 3), and both schemes (category 4).
- Data Analysis:**
  - Machine learning models were used to construct predicted probabilities of inclusion under each cost-based scheme.
    - Data were partitioned into 75% training and 25% test sets by race/ethnicity.
    - Ensemble predictions were generated from the consensus model using soft voting across five algorithms: regularized logistic regression, random forest, gradient boosted trees, support vector machines, and multilayer perceptron neural networks.
  - Multivariable multinomial logistic regression assessed associations between race/ethnicity and the four-level outcome derived from predicted inclusion.
    - Comparison between categories 2 & 3 showed racial/ethnic differences.

## RESULTS

- The total study population consisted of 1,848,654 beneficiaries, with consistent racial/ethnic differences in patient characteristics (Table 1).
- Compared with their non-Hispanic White (White) counterparts, Black and Hispanic beneficiaries showed higher proportions of inclusion in category 3 (based on hospitalization/ER costs only) than in category 2 (total healthcare only), whereas Asian and Other groups showed the opposite pattern (Table 2).
- Similar racial/ethnic patterns were observed after adjusting for all patient characteristics: Black (relative risk ratio [RRR] = 4.31, 95% confidence interval [CI] = 3.92–4.75) and Hispanic (RRR = 2.28, 95% CI = 2.04–2.56) groups exhibited significantly higher likelihood of being classified in category 3 relative to category 2 than White beneficiaries, while Asian (RRR = 0.24, 95% CI = 0.19–0.29) and Other (RRR = 0.43, 95% CI = 0.36–0.52) groups had lower likelihood (Table 3).

## TABLES/FIGURES

Table 1. Characteristics of test population by race/ethnicity

Characteristics	Non-Hispanic White (n = 372,301; 80.56%)	Black (n = 37,110; 8.03%)	Hispanic (n = 25,373; 5.49%)	Asian/Pacific Islander (n = 13,313; 2.88%)	Other (n = 14,068; 3.04%)
<b>Predisposing factors</b>					
Age, mean (SD)	73.06 (11.21)	66.43* (14.99)	69.45* (14.15)	74.32* (11.14)	68.39* (12.09)
Male, n (%)	156,199 (41.96)	15,111* (40.72)	10,789 (42.52)	5,493 (41.26)	7,830* (55.66)
Original reason for Medicare enrollment, n (%)					
OASI	292,986 (78.70)	17,790* (47.94)	15,564* (61.34)	11,272* (84.67)	10,842* (77.07)
DIB	78,226 (21.01)	18,112 (48.81)	9,188 (36.21)	1,868 (14.03)	3,098 (22.02)
ESRD	577 (0.15)	584 (1.57)	352 (1.39)	115 (0.86)	76 (0.54)
DIB and ESRD	512 (0.14)	624 (1.68)	269 (1.06)	58 (0.44)	52 (0.37)
Low-income subsidy, n (%)	80,859 (21.72)	23,015* (62.02)	17,311* (68.23)	7,585* (56.97)	4,238* (30.13)
Percentage of non-White population, mean (SD)	30.92 (19.31)	47.89* (18.21)	55.65* (21.82)	54.75* (18.84)	37.91* (21.42)
Proportion of married-couple families, mean (SD)	72.26 (6.12)	65.38* (7.96)	68.35* (6.34)	70.38* (6.22)	71.28* (6.97)
Proportion with education ≥ high school, mean (SD)	88.70 (4.71)	86.99* (4.67)	83.93* (7.32)	87.30 (5.18)	88.74 (4.73)
Per capita income (in \$1,000), mean (SD)	54.94 (18.84)	54.66 (19.51)	57.75 (23.31)	70.13* (25.94)	58.75* (22.28)
Proportion without health insurance, mean (SD)	10.34 (4.65)	11.13* (4.53)	12.49* (6.49)	9.12* (4.22)	10.26 (4.77)
<b>Enabling factors</b>					
Metropolitan statistical area, n (%)	283,974 (76.28)	31,677* (85.36)	22,627* (89.18)	12,771* (95.93)	11,120* (79.04)
Health Professional Shortage Area, n (%)	340,110 (91.35)	35,586* (95.89)	24,543* (96.73)	12,553 (94.29)	13,076* (92.95)
Census region, n (%)					
Northeast	75,159 (20.19)	5,754* (15.51)	4,495* (17.72)	2,381* (17.88)	3,080* (21.89)
Midwest	95,129 (25.55)	6,829 (18.40)	2,401 (9.46)	1,381 (10.37)	3,080 (21.89)
South	136,520 (36.67)	21,644 (58.32)	8,049 (31.72)	2,633 (19.78)	3,998 (28.42)
West	65,493 (17.59)	2,883 (7.77)	10,428 (41.10)	6,918 (51.96)	3,910 (27.79)
<b>Need factor</b>					
Risk adjustment summary score, mean (SD)	1.22 (1.20)	1.56* (1.67)	1.45* (1.51)	1.27 (1.22)	1.07* (1.16)

Abbreviation: SD = standard deviation; OASI = old age and survivors insurance; DIB = disability insurance benefits; ESRD = end-stage renal disease. \* Indicates a statistically significant difference from non-Hispanic White patients (P < 0.05).

## TABLES/FIGURES

Table 2. Distribution of predicted inclusion in the top quartile of costs among the test population by race and ethnicity based on the consensus model

Outcome categories	Non-Hispanic White, n (%)	Black, n (%)	Hispanic, n (%)	Asian/Pacific Islander, n (%)	Other, n (%)
1	268,763 (72.19)	21,696* (58.46)	16,393* (64.61)	10,311* (77.45)	11,150* (79.26)
2	14,691 (3.95)	1,008 (2.72)	947 (3.73)	927 (6.96)	737 (5.24)
3	14,220 (3.82)	2,605 (7.02)	1,176 (4.63)	126 (0.95)	183 (1.30)
4	74,627 (20.04)	11,801 (31.80)	6,857 (27.02)	1,949 (14.64)	1,998 (14.20)

Outcome categories: 1 = not predicted to be in the top quartile for either total healthcare costs or combined hospitalization and emergency room (ER) costs; 2 = predicted to be in the top quartile for total healthcare costs but not for combined hospitalization and ER costs; 3 = predicted to be in the top quartile for combined hospitalization and ER costs but not for total healthcare costs; 4 = predicted to be in the top quartile for both total healthcare costs and combined hospitalization and ER costs. \* Indicates frequency distribution was significantly different from non-Hispanic White patients (P < 0.05).

Table 3. Multinomial logistic regression results for inclusion in predicted top-quartile cost categories (category 3 vs category 2) based on the consensus model

Characteristics	Relative risk ratio	95% confidence interval
<b>Predisposing factors</b>		
Race/ethnicity		
Black	4.31	3.92–4.75
Hispanic	2.28	2.04–2.56
Asian/Pacific Islander	0.24	0.19–0.29
Other	0.43	0.36–0.52
Age	1.108	1.105–1.112
Male	0.61	0.58–0.64
Original reason for Medicare enrollment		
Disability insurance benefits (DIB)	1.98	1.81–2.17
End-stage renal disease (ESRD)	0.04	0.01–0.28
DIB and ESRD	0.17	0.07–0.41
Low-income subsidy	2.06	1.91–2.22
Percentage of non-White population	0.977	0.975–0.980
Proportion of married-couple families	0.964	0.958–0.971
Proportion with education ≥ high school	1.03	1.02–1.05
Per capita income (in \$1,000)	0.974	0.971–0.976
Proportion without health insurance	0.999	0.991–1.008
<b>Enabling factors</b>		
Metropolitan statistical area	0.74	0.69–0.80
Health Professional Shortage Area	0.98	0.89–1.07
Census region		
Midwest	1.26	1.14–1.40
South	1.15	1.03–1.28
West	1.81	1.55–2.10
<b>Need factor</b>		
Risk adjustment summary score	0.28	0.27–0.30

Reference groups: outcome category 2, non-Hispanic White, female, qualifying through old age and survivor's insurance, non-receipt of low-income subsidy, non-metropolitan statistical area, non-Health Professional Shortage Area, and northeast census region.

## STUDY LIMITATIONS

- The study relied on a top-quartile cutoff to identify beneficiaries with high spending; alternative thresholds may yield different racial/ethnic inclusion patterns.
- Predicted eligibility did not account for plan-level processes, such as outreach, beneficiary response, and provider participation, that may influence actual MTM receipt.
- Administrative claims data may not fully capture clinical, behavioral, or socioeconomic factors that affect healthcare utilization and MTM eligibility.
- The predictive validity of machine learning models depends on available features, and unmeasured determinants may contribute to residual confounding.
- Findings based on fee-for-service Medicare may not generalize to Medicare Advantage or other populations.
- The cross-sectional design precludes assessment of causal relationships or changes in cost patterns over time across racial/ethnic groups.

## CONCLUSIONS

- Cost-based MTM eligibility schemes would yield different patterns of eligibility across racial/ethnic groups depending on the component used, suggesting that reliance on a single cost measure may differentially capture subpopulations and affect equity in MTM eligibility.
- The hospitalization/ER cost-based scheme, relative to the total healthcare cost-based scheme, would result in greater inclusion of Black and Hispanic beneficiaries and lower inclusion of Asian and Other beneficiaries compared with White beneficiaries.
- While the hospitalization/ER-based criterion may help reduce some disparities in MTM eligibility, additional complementary eligibility criteria are needed to better identify populations not reached by the MTM framework.
- As data-driven tools become more widely used, continuous monitoring of algorithmic outputs, model design transparency, and the use of fairness metrics are needed to support equitable access to MTM services.

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