

Factors Associated with Performance Among Optometrists in Alberta, Canada: A Predictive Analysis

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Abstract

Background

Risk and protective factors influencing the performance of health professionals are of significant interest to regulators and the public. We aimed to develop a predictive model to identify factors influencing optometrist performance, providing insights for improving regulatory oversight and supporting targeted interventions.

Methods

In our retrospective cohort study, we analyzed data from optometrists registered between 1987 and 2019 in the Alberta College of Optometrists Continuing Competence (CC) program to develop a predictive model for CC practice review outcome. We evaluated reviews using self-assessments, onsite visits, and clinical evaluations, with pass or fail status as the primary outcome. Key covariates included sex, age, training location, and previous review scores. We used a generalized additive model with a logit link and assessed its performance using five-fold cross-validation. Sensitivity and specificity were assessed with a holdout testing set.

Results

We analyzed 2,075 CC reviews of 916 optometrists. Of these reviews, 75.6% received a passing grade. Practitioners were primarily male (51.7%, 48.3% female) and trained in the United States (49.8%) or Canada (46.2%). Significant predictors of review outcome were sex, training location, previous review score, follow-up score, age (included as a nonlinear effect varying by sex), and years since last review. In developing a selection tool for future assessments, we replaced age with years since graduation and removed training location. Among the 388 practitioners selected for assessment since 2021, practitioners flagged as high risk had significantly higher failure rates (16.1%) compared with practitioners selected randomly (3.0%).

Discussion

Male sex, years since graduation, and poor outcomes on previous reviews emerged as significant predictors of failing an assessment. The developed selection tool effectively identified high-risk practitioners for reassessment, supporting fair and efficient resource allocation in the CC program.

Conclusions

Key factors influencing CC review outcomes were identified and a selection tool was developed to ensure fairness across subgroups defined by age and sex.

Keywords

optometrists, Continuing Competence, predictive modelling, risk factors, selection tool, Alberta

Audit and feedback are widely used by regulatory bodies as strategies to improve professional practice, either independently or as a component of multifaceted quality improvement initiatives.¹ The primary goal of overseeing health professions is to safeguard public safety by ensuring that health care services are delivered by licensed, competent, qualified, and ethical professionals. Through the establishment and enforcement of regulations, conducting audits, and continuous monitoring of compliance, regulatory bodies foster trust in the health care system by encouraging practitioners to maintain high standards of care.²

The exploration of factors affecting medical doctors' practice has been the subject of numerous studies.³ Factors such as age, sex, and location of training have been associated with increased risks of complaints, professional liability claims, and impaired practice by physicians.³⁻⁶ In Canada, the College of Physicians & Surgeons of Alberta (CPSA) conducted a pioneering study on risk and protective factors associated with complaints about physicians (CPSA, unpublished). That study yielded preliminary models outlining some of these factors among physicians. Protective factors included increasing hours spent teaching and having hospital privileges. Risk factors for performance included high patient volume, older physician age, male, specialty (e.g., surgeons or family physicians), and others.

Building on this approach, the Alberta College of Optometrists (ACO) collaborated with the CPSA to explore whether similar factors are associated with the performance of optometrists in Alberta.

Previous studies conducted in North America and the United Kingdom have investigated factors influencing the performance of optometrists, including clinical skills, practitioner–patient relationship, business management, technological advancements, education, and socioeconomic conditions.^{5,7,8} In 2019, the General Optical Council in the United

Kingdom commissioned research to understand the primary competency, conduct, and contextual risks for optometrists and dispensing opticians in the optical professions.⁷ The research suggested that risks linked to the practice environment were seen as more likely to occur in everyday practice than risks arising from physicians' skills or behaviour. Time constraints with patients, commercial and performance target pressures, inadequate staffing, and working as a locum were identified as the most probable risk factors by both optometrists and dispensing opticians.⁷

Despite these insights, a noticeable deficiency remains in identifying individual optometrists whose performance could improve with support from regulatory bodies. Furthermore, a comprehensive understanding of the factors influencing optometrists' performance in Alberta remains relatively underexplored. Addressing this research gap is crucial for developing evidence-informed selection tools and improving the targeting and impact of competence assessments.

Our aim for this project was to develop a model for optometrists' performance that can be used by the ACO to:

1. Identify performance-predicting factors that overlap between optometry and other health care professions; and
2. Improve the selection criteria for practitioners who may benefit from targeted interventions, additional support, or both.

By creating a predictive model tailored to Alberta optometrists, our research provides actionable insights to improve the regulatory oversight of optometric practice in Alberta.

Methods

Ethical approval for our study was obtained from the University of Alberta's Health Research Ethics Board - Health Panel (Pro00116934).

The ACO administers a comprehensive Continuing Competence (CC) program designed to ensure minimum standards of professional practice by optometrists in Alberta. Launched in 2015, this program mandates that all newly registered optometrists undergo assessment in their first year of practice, followed by reassessments every four to five years or as directed by the ACO's Complaints Director. The CC program consists of the following components.

Suggested citation

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- **Onsite visits:** Direct evaluations of clinical practice environments, including a self-assessment questionnaire completed by optometrists. This questionnaire covers topics such as after-hours care, the types of services offered, confirmation of having the necessary equipment for adequate ocular health assessment, and compliance with privacy legislation.
- **Continuing professional education (CPE) evaluation:** Assessment of CPE activities taken by optometrists.
- **Validation of clinical practice:** A thorough review of clinical records and decision-making processes.

Optometrists are assigned scores on a 1-5 scale during these assessments.

- Scores of 1 to 2 indicate a passing grade and satisfactory performance.
- A score of 3 requires immediate changes and written confirmation, but it is not considered a failure in regulatory terms. However, for our study, we included it as the failure cut-off due to the low number of scores of 4 and 5.
- A score of 4 is unsatisfactory and requires a mandatory follow-up within 180 days.
- A score of 5 denotes the lowest level of performance and is considered unsatisfactory, leading to referral to the Complaints Director.

We used a retrospective, population-based cohort analysis of the CC reviews of the 1,058 optometrists registered with the ACO between 1987 and 2019. After excluding 19 reviews with missing data and 142 practitioners with no reviews, the final analytic sample included 2,075 CC reviews from 916 optometrists.

Our primary objective was to develop a predictive model of CC practice review outcomes, specifically to identify and interpret various factors predictive of failing review scores.

Primary Analysis

The primary outcome in this analysis was the pass or fail status of each CC review, obtained by dichotomizing scores on the 1-5 scale.

We conducted an analysis of this outcome with a generalized multivariable additive model (with a logit link function) fit using de-identified data from the ACO. As model covariates, we considered practitioner sex;

age; training location (that is, in Canada, the United States, or other); number of years since the practitioner's last review (or graduation, in the case of a practitioner's first review); number of years since graduation; previous review score (or no previous review) for each of the two most recent reviews; follow-up score for the previous review (that is, pass, fail, or no previous follow-up review); and review number.

In a model selection procedure, we considered the above factors, potential nonlinear effects for continuous variables, and various interaction structures between continuous and categorical variables. We used five-fold cross-validation to assess predictive performance via the area under the curve (AUC) for the receiver operating characteristic (ROC). For brevity, we present only the final model in this article.

To assess the predictive performance of the final model, we used a holdout testing set including about 10% of the analytic sample. We evaluated the model's sensitivity and specificity on both the training and testing sets by thresholding predictions using the optimal cut-off identified as the point closest to the top-left corner of the training ROC curve, which reflects the maximal combined sensitivity and specificity).

We conducted all analyses in R and fit the main model using the *mgcv* package (version 1.8-38).⁹ We assessed statistical significance with standard type-3 ANOVA tests (when testing overall covariate significance) and Wald tests (for individual model parameters), with a significance level of 0.05.

Selection Tool Development

Based on the results of the main analysis and further collaboration with the ACO, we developed a tool to select who would receive CC reviews by identifying practitioners at higher risk of failing. The previous model could disproportionately target specific subgroups of practitioners (e.g., by age or sex). To address this potential and perceived risk, we designed the tool according to a fairness principle.¹⁰ The tool defines fairness as equal opportunity across subgroups. Practitioners who would genuinely pass their next review should have the same probability of not being flagged, regardless of subgroup membership.

Subgroup membership refers to a division of the practitioner population with one or more characteristics. We define four subgroups based on age and sex: males 40 years and older, males younger than 40, females 35 and older, and females younger than 35.

These age thresholds approximate the median age across CC reviews for each sex and were chosen for convenient cut points and not to imply traditional career stage classification. One way to achieve fairness in practice is to set a different threshold in each subgroup for what defines an at-risk practitioner. Determined from an ROC curve for each practitioner subgroup, we chose these thresholds to achieve the same specificity across the groups.

Our tool selected practitioners for review in three stages. First, it flagged practitioners with a risk score above their respective subgroup threshold (that is, high-risk practitioners). Second, a predefined number of high-risk practitioners were selected for review. The number of practitioners selected from each subgroup was proportional to the size of the subgroup in the practitioner population. Third, a set number of practitioners not flagged by the model were randomly selected for review. The number of high-risk reviews and random reviews were determined by ACO based on operational capacity and regulatory priorities. This randomly selected subset of practitioners was included as a reference group to assess the predictive ability of the model.

Results

Cohort Characteristics

From the original ACO dataset of 2,094 CC reviews, we removed 19 (0.9%) due to obvious entry errors or incomplete data — nearly always due to a missing review score. The final analytic sample included 2,075 CC reviews from 916 unique practitioners. Of these reviews, 1,569 (75.6%) received passing scores and 506 (24.4%) received failing scores. Table 1 provides a detailed summary of the analytic sample at the review level.

About half of the 916 practitioners in the analytic sample were male (474, 51.7%, 442 female, 48.3%). Nearly all practitioners were trained in the United States (456, 49.8%) or Canada (423, 46.2%), with a small proportion trained in other countries (37, 4.0%). Most practitioners received one (285, 31.1%), two (310, 33.8%), or three (168, 18.3%) CC reviews during the study period. The remaining 153 (16.7%) practitioners received four or more reviews.

Model Results

The final model included sex, training location, previous CC review score, follow-up score for the previous

Table 1: Summary of CC reviews ($n = 2,075$)

Variable	$n(\%)$ or Median (Q1, Q3)
Male*	858(41.3%)
Female*	1,217(58.7%)
Age, years	35.0 (30.0, 46.0)
Training in Canada*	1,088(52.4%)
Training in the United States*	932(44.9%)
Training in other location*	55(2.7%)
Time since last review (or graduation), years	4.0 (2.0, 7.0)
Previous review score 1	543(26.2%)
Previous review score 2	350(16.9%)
Previous review score 3	144(6.9%)
Previous review score 4	116(5.6%)
Previous review score 5	6(0.3%)
No previous review [†]	916(44.1%)
Previous review score (follow-up) [‡] 1	64(74.4%)
Previous review score (follow-up) [‡] 2	21(24.4%)
Previous review score (follow-up) [‡]	15(17.4%)
Fail score 3 to 5	

*Summaries are presented at the review level.

[†]Represents the first observed review for each of the 916 unique practitioners in the analytic sample.

[‡]Only reported where follow-up reviews were administered by the ACO. Percentages are calculated for the total number of follow-up reviews.

review, review number, age (with a nonlinear effect interacting with sex), and time since the last review. Table 2 summarizes effect estimates for the fitted model. On the training set, the model had an AUC of 0.66, a specificity of 0.64, and a sensitivity of 0.60. On the testing set, AUC was 0.63, specificity was 0.63, and sensitivity was 0.57.

After accounting for other factors, practitioner sex had a significant association with review outcome ($P = .001$). All else being equal, male practitioners had 60% higher odds of failing a CC review than female practitioners.

Practitioner age had a significant nonlinear association with review outcome that differed by practitioner sex ($P < .001$). These estimates are displayed in Figure 1. For female practitioners, age was not

Table 2: Parameter estimates and odds ratios from the fitted model

Variable	Effect estimate	Odds ratio	Estimate standard error	P value
Intercept	-1.95	—	0.22	<.001
Male*	0.47	1.60	0.14	.001
Training location†	—	—	—	.003
The United States	0.23	1.26	0.12	.06
Other	1.00	2.73	0.32	.002
Previous review score‡	—	—	—	.04
1	-0.52	0.60	0.22	.02
2	-0.25	0.78	0.22	.26
3	0.01	1.01	0.28	.96
4	0.56	1.75	0.52	.29
5	0.83	2.30	0.97	.39
Follow-up score for the previous review	—	—	—	.72
1	-0.42	0.66	0.56	.46
2	0.18	1.19	0.69	.80
Fail	-0.18	0.83	0.77	.81
Review number	0.14	1.15	0.09	.14
Years since last review (or graduation)	-0.03	0.97	0.01	.03
Age (by gender) [¶]	—	—	—	<.001
Female	—	—	—	.52
Male	—	—	—	<.001

* Reference category: Female

† Reference category: Canada

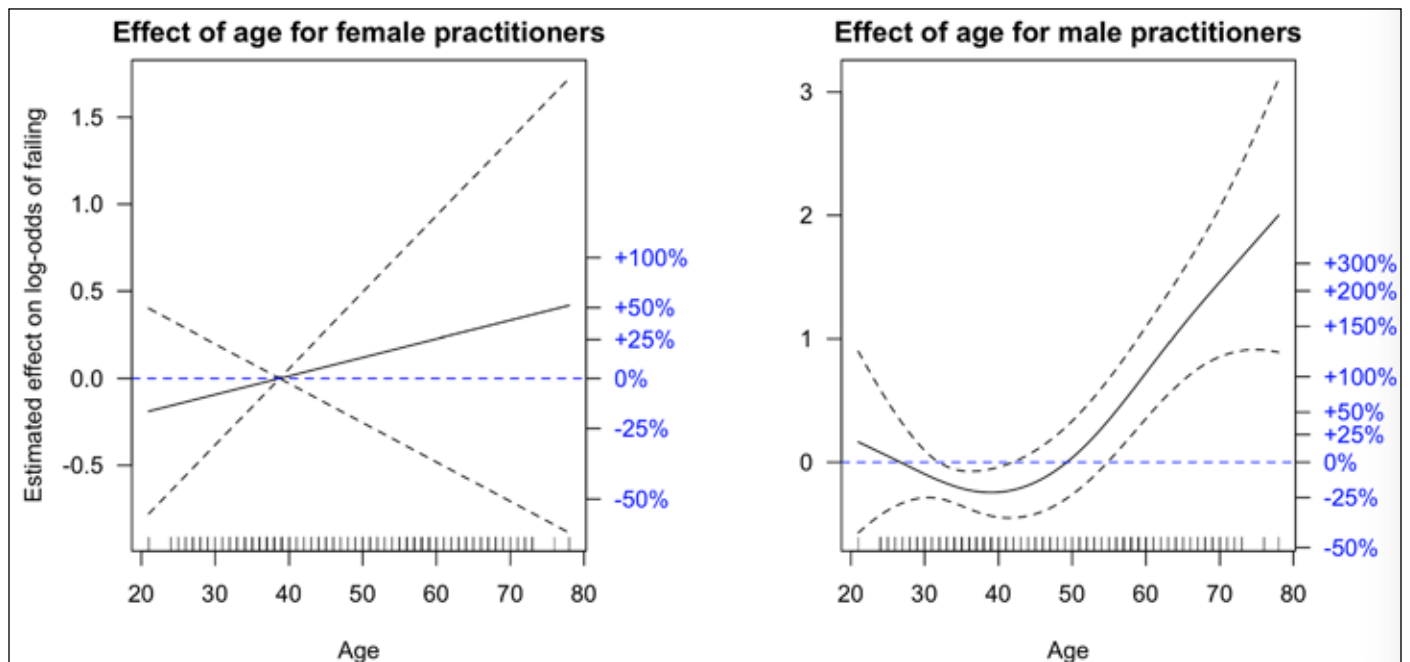
‡ Reference category: No previous review

^{||} Reference category: No follow-up review

[¶] Nonlinear effects presented in Figure 1.

Note: For categorical variables, odds ratios are the relative odds of failing a CC review associated with each covariate, relative to the specified reference category. For continuous covariates, such as the number of years between the review and graduation, it is the relative effect of one additional review or one additional year since graduation, respectively.

—, statistics not computed for reference categories, the model intercept (which has no associated odds ratio), or for the nonlinear effects of age (which cannot be summarized in this table but is presented in the main text).

Figure 1. Effect of age on the log-odds of failing a review for female and male practitioners

Dotted lines indicate 95% confidence intervals. The right axis (in blue) indicates percent change in the odds of failing relative to a 39-year-old female practitioner or 50-year-old male practitioner.

significantly associated with review outcome ($P = .52$). This association was significant for male practitioners ($P < .001$), whose odds of failing decreased until about 39 years of age and increased afterwards. All else being equal, 39-year-old male practitioners had about 25% lower odds of failing compared to 27- or 50-year-old male practitioners.

After controlling for other factors, training location had a significant association with CC review outcome ($P = .003$). Practitioners who trained outside of Canada and the United States had about 170% higher odds of failing a review compared with those trained in Canada. However, because only 37 practitioners (with 55 reviews) trained outside of Canada or the United States were represented in the dataset, this estimate should be interpreted and generalized with caution.

Previous review score was also significantly associated with CC review outcome ($P = .04$) after controlling for other factors. The odds of failing were higher among practitioners who had worse scores on their previous review (Table 2). All else being equal, practitioners without a previous review were comparable

with those who received a score of 3 on their previous CC review.

Finally, the number of years since a practitioner's last review (or graduation) had a significant association with review outcomes ($P = .03$). Holding all else constant, each additional year since a practitioner's last review was associated with a 3% reduction in the odds of failing a CC assessment ($P = .03$). This may reflect that more-experienced practitioners — who tend to go longer between reviews — were less likely to fail, or it may suggest a selection effect, where higher-risk individuals were selected and reassessed earlier.

Selection Tool

To improve the tool's optics, focus on fairness, and feasibility of the selection strategy (given operational restrictions), we modified the model following discussion with the ACO team members. We replaced age with number of years since graduation (as a measure of practitioner experience), removed review number and training location, and allowed the effect of year to vary by practitioner subgroup. None of these changes had a substantial impact on the interpretation or performance of the model. We chose to remove training

location due to the small number of practitioners in Alberta who were trained outside of Canada and the United States and the nonsignificant difference in the odds of failing between practitioners trained in Canada versus the United States (Table 1). Risk factors for failure in CC assessment identified by the updated model were male sex, increased years since graduation from an optometry program, and previous CC assessment review score.

Since the implementation of the model-based risk selection tool in 2021, 388 optometrists were selected for a competence assessment (155 risk based and 233 random). In the risk-based subsample, 77 practitioners (49.7%) received a review score of 3, 4, or 5, while 25 (16.1%) received a grade of 4 or 5. Among the random subsample, 85 practitioners (36.5%) received a grade of 3 or higher, while 7 (3.0%) received a grade of 4 or higher. These differences in failure rates (with either 3-5 or 4-5 as failing scores) between the selected high-risk practitioners and those selected at random were statistically significant ($P \leq 0.01$ in separate two-sample proportion tests).

Discussion

With our study, we aimed to develop a predictive model of factors associated with performance among optometrists in Alberta using practice review outcomes from ACO's CC program. The findings have significant implications in the understanding of optometrist performance and highlight the potential for developing predictive tools to help regulatory bodies effectively identify health practitioners at risk of underperformance.

Our results identified key risk factors for failing a CC review, including male sex, increased age, or years since graduation (both measures of amount of experience), and previous review outcomes. These findings echo trends observed in studies of other health professions, such as physicians and pharmacists, suggesting that male sex and older age may be generalizable risk factors across multiple health care professions.¹¹⁻¹³ In our study, male optometrists had 60% higher odds of failing a review compared to their female counterparts, even after adjusting for training location, previous review scores, and time since the last review. This aligns with findings in pharmacists by Fielding et al., who also noted a persistent sex disparity in performance outcomes.¹⁴

The significant observation in our study was the nonlinear relationship between age and performance among male optometrists. The odds of failing a review decreased until about 39 years of age, after which it began to increase, suggesting a U-shaped relationship. This trend highlights that younger and older male practitioners may be particularly at risk, while midcareer practitioners are less likely to fail. Interestingly, this age-related trend was not observed among female optometrists, indicating that additional unmeasured factors may influence female performance outcomes differently.

While we did not explicitly include an indicator the first year of practice as a covariate, about 87% of first reviews occurred within three years of initial registration. As such, the influence of early practice is largely captured by the no previous review category in our model. Our findings showed that the risk associated with the absence of a previous review is similar to optometrists with a previous score of 3, suggesting the early-career review itself does not, in itself, confer a higher risk. However, younger age — particularly among male practitioners — was associated with higher failure risk. This implies that any elevated early-career risk is more strongly attributable to age than to timing of the first review. We acknowledge that this interpretation is limited by the lack of data on prior clinical experience outside Alberta, which may mean that some first reviews occurred after years of independent practice in other jurisdictions.

Training location emerged as a significant factor, with optometrists trained outside Canada and the United States showing higher odds of failing a CC review. However, this estimate was based on a limited number of internationally trained practitioners in our sample, which may have reduced the precision of this effect. As such, this variable was excluded from the final risk-based selection tool but is discussed here due to its consistent association and relevance in the broader regulatory context.^{15,16} Nevertheless, caution is warranted when generalizing this result due to the limited representation of optometrists trained outside of Canada and the United States in the dataset.

The factors identified in our study as being associated with optometrist performance are consistent with findings from other health care professions.^{11,12} The association between training location and performance has also been documented in medicine, where internationally trained practitioners often face

additional challenges due to differences in health care systems, educational approaches, or patient expectations.¹⁷ These parallels emphasize the importance of understanding contextual and demographic factors in regulatory oversight.

Furthermore, the finding that previous review scores are strong predictors of future performance aligns with the broader literature on competency assessment. Studies of physician performance suggest that those who perform poorly on early assessments are more likely to continue struggling over time, emphasizing the importance of early identification and intervention to support professional development.^{18,19}

While underperformance on a CC review is intended to flag potential concerns with practice quality, it has not been formally validated against patient harm, complaints, litigation, or disciplinary actions. This gap highlights the need for further research to determine whether CC performance reliably reflects real-world risk.

Our findings also suggest that current remediation strategies alone may not be sufficient to fully address the risk of repeated underperformance. Practitioners with previous poor scores remained more likely to fail subsequent reviews (even when accounting for follow-up reviews), indicating a need to re-evaluate the effectiveness and intensity of existing interventions.

Even so, regular monitoring and competence reviews play an important role in identifying practitioners at elevated risk of underperformance before significant issues arise. Strengthening both the assessment and remediation components of the CC process could enhance its ability to protect patients and uphold professional standards.

The development of a predictive tool based on the factors identified in our study offers a significant opportunity for regulatory bodies, such as the ACO, to enhance the efficiency and fairness of their CC review processes.

While our study focused on identifying practitioners at elevated risk of underperformance, the ultimate goal of competence assessment is not only detection but also improvement. Evidence from a recent Cochrane review by Ivers et al. highlights that audit and feedback interventions are most effective when paired with structured follow-up, goal setting, actionable guidance, and when feedback is delivered by a respected peer or supervisor.²⁰ Future enhancements to the ACO's CC program could consider integrating

such components to ensure that flagged practitioners are not only identified but also supported in making meaningful improvements.

By flagging practitioners at higher risk of failing a review, regulatory bodies can allocate resources more effectively, targeting support and interventions where they are most needed. Importantly, the fairness principle¹⁰ built into the tool ensures that the model does not disproportionately target specific subgroups of practitioners, particularly with respect to sex and age. The introduction of a risk threshold for each subgroup based on ROC curves is a novel approach in medical regulation that ensures equal selection likelihood across practitioner demographics. By applying subgroup-specific thresholds while maintaining consistent predictive specificity across groups, the tool minimizes the risk of introducing bias into the review process. This is particularly important given the significant associations between sex and age with performance outcomes.

The findings from our study underscore the value of data-driven, evidence-based regulatory practices that balance fairness and efficiency. By using predictive models, regulatory bodies could support continuous quality improvement, enhance professional development, and strengthen the public's trust in the health care system.

Limitations and Future Directions

While the predictive model developed in our study offers valuable insights, several limitations must be acknowledged. First, the study's sample was limited to optometrists in Alberta, and thus the findings may not be fully generalizable to other provinces, territories, or countries where regulatory practices and health care contexts may differ. Second, sex was recorded as binary (that is, male or female) in the dataset. Future research should include broader gender identity categories to support more inclusive analyses. Third, the small sample of internationally trained optometrists limits the ability to draw strong conclusions about the impact of training location on performance. Future research with larger and more diverse samples could provide a more comprehensive understanding of this factor.

Moreover, the AUC of the model (0.66 for the training set and 0.63 for the testing set) suggests that while the model is useful, there is room for improvement in its predictive performance. Incorporating

additional covariates — such as practice characteristics, patient demographics, or detailed information about practitioners' clinical or communication skills — may enhance the model's accuracy and help identify more nuanced predictors of optometrist performance. Further refinement of the model could lead to a more robust tool for identifying at-risk practitioners.

Future studies should also explore the integration of qualitative data to complement quantitative findings, providing richer insights into the contextual factors influencing optometrist performance. Expanding research to include comparisons across jurisdictions or health care systems could further validate and enhance the applicability of the model.

Conclusions

Our study identified three predictive factors associated with performance on the ACO's CC program, which are male sex, older age, and poor performance on previous competence reviews. These findings are consistent with similar research on other health care professions, suggesting that certain risk factors may be shared across disciplines. The development of a predictive tool based on these factors offers regulatory bodies a valuable resource to identify at-risk practitioners while promoting fairness in the review process. By using data-driven approaches, regulatory bodies could focus prevention and remediation resources on practitioners most in need of such support. Further research could refine predictive models by incorporating additional variables and testing their applicability in diverse contexts, with the aim of supporting regulatory efficiency, fairness, and quality improvement in health care professions.

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