

Supplement to:

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Online Supplement for "Differences in academic preparedness do not fully explain Black-White enrollment disparities in advanced high school coursework"

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Online Supplement A "Favorable" enrollment decisions and the notion of academic preparedness

At a conceptual level, measuring whether advanced enrollment processes favor one race group over another depends heavily on what "favoring" is defined to mean. Two approaches stand out in the literature.

First, by directly adjusting for many student- and school-level factors in addition to student race, traditional regression-based approaches implicitly seem to conceive of advanced enrollment "favoring" a group in terms of the extent to which student race implicitly or explicitly influences gatekeepers' decisions — i.e., the extent to which there is disparate treatment in such decisions (Gaebler et al. 2022; Greiner and Rubin 2011; Jung et al. 2019; Lucas 2009). However, disparate treatment is not the only reason why one might consider an enrollment process to favor a race group, as selection criteria, both formal and informal, implemented in a school may affect one race group more than another, even when nominally race-neutral. Such selection criteria may have an unjustified *disparate impact* (Gaebler et al. 2022; Jung et al. 2019) on students of certain race groups if those students enroll at lower rates, and if the selection criteria has little relevance to stated principles governing course enrollment. We note that in general, the process through which students are placed into advanced courses are complex, and actions of gatekeepers are not the only factor shaping them. Schools' eligibility criteria, the actions of parents, of teachers, and of students themselves can all influence enrollment in advanced coursework (Kelly 2007; Lewis and Diamond 2015; Oakes and Guiton 1995; O'Connor et al. 2011; Tyson 2011).

In line with the legal notion of *disparate impact*, a second conceptualization of what it means for enrollment decisions to "favor" a given race group focuses on whether enrollment disparities across race groups can be fully explained by the principles guiding course enrollment. Scholars recognize that while enrollment decisions in advanced coursework are

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complex, and can involve the weighing of many factors, these decisions, at least ostensibly, are often claimed to rely on the notion of *academic preparedness* (College Board 2023; Kelly 2007; Kelly and Price 2011; Lewis and Diamond 2015; Oakes and Guiton 1995; Tyson 2011), i.e., the idea that students should be assigned to the academic environment which best matches their prior academic experiences and current academic capabilities. In this sense, academic preparedness emerges as a key concept in assessing whether enrollment decisions tend to favor a given group. To further illustrate that academic preparedness is often central to enrollment decisions, we discuss in more detail the principle which guides student selection into Advanced Placement courses (the empirical context to which we apply our approach).

The AP selection principle. The general principle governing student enrollment into AP coursework is established by the College Board:

The AP Program believes that all motivated and academically prepared students should be able to enroll in AP courses. We strongly encourage all high schools to follow this principle.

Some high schools let any student enroll in an AP course as long as the student has taken the recommended prerequisite courses. Other high schools have additional rules—for example, you might have to pass a placement test to enroll in an AP course. Ask your counselor what the process is at your school (College Board 2023).

Following this principle, we consider AP placement processes to favor a race group if racial disparities in enrollment cannot be traced back to differences in academic preparedness that exist before enrollment decisions occur.

We emphasise the notion of academic preparedness, rather than student motivation, for two reasons. First, it is difficult to dissociate student motivation for taking AP courses from the enrollment process itself. It is possible, even likely, that some of the observed Black-White disparities in AP participation can be explained by differences in student motivation to enroll, since feelings of belonging in advanced courses are often racialized (Francis and Darity 2020, 2021; Nasir and Vakil 2017; O'Connor et al. 2011; Tyson et al. 2007). However, evidence suggests that such different feelings of belonging across Black and White students are unlikely to emerge independently of the enrollment process. For example, studies show that Black-White differences in feelings of belonging as well as racialized peer pressures against academically-oriented behaviors arise primarily in settings where Black students are underrepresented in advanced courses; this pattern encourages students to equate school success with Whiteness (Tyson 2011). This understanding of student agency suggests that racial differences in student preferences for AP enrollment are entangled with existing racial disparities in AP enrollment, and therefore should be not be considered as a justification for such disparities. Second, even if differences in student motivation exist prior to AP enrollment, it strikes us as reasonable to assume that part of the function of an enrollment process is to emphasize preparedness over motivation. That is, from a policy perspective, it seems useful for schools to try to ensure that all academically prepared students enroll in a course—especially a course that is likely to have a positive influence on subsequent educational outcomes—even if this means being responsible for influencing students' motivation.

The College Board does not specify exactly what constitutes adequate academic preparedness; this is left to the interpretation of school staff, allowing school-level processes to be highly influential on students' chances of AP enrollment. Although schools can vary considerably in how they structure student placement into AP courses (Kelly 2007), a general pattern stands out: schools take into consideration students' academic history together with the preferences of parents and of students themselves (Gamoran 1992; Kelly and Price 2011; Oakes and Guiton 1995; Tyson 2011). In particular, a minimum level of academic qualification is usually a necessary requirement for enrollment into an AP course, and if this requirement is met, then students' and parents' preferences are subsequently taken into account (Oakes and Guiton 1995).

This complex process of AP course enrollment admits several avenues for racial disparities to arise between students who have similar levels of academic preparedness. Besides the possibility of differences in student motivation and unjustified disparate impacts of various eligibility requirements, as noted above, studies suggest that factors such biased teacher recommendations (Ferguson 1998; Irizarry 2015; Oakes 2005; Oakes and Guiton 1995; Ready and Wright 2011; Tyson 2011), and racial differences in parental involvement (Lewis and Diamond 2015; Lewis-McCoy 2014; Tyson et al. 2005) can all contribute to racial disparities in AP enrollment between similarly prepared students of different races in a given school.

Online Supplement B Detailed sample description

In Table S.B.1, we provide additional detail on the trajectory of students in our data, after restricting our focus to the 115 high schools satisfying the criteria outlined in Sample subsection of the Data and Measures section in the main text (we refer to these schools as "eligible high schools"). For ease of exposition, we present results for the 2012 cohort (i.e., students who began 9th grade in 2012), but patterns are similar for the 2011 cohort. In the Fall of 2012, there were 46,890 9th graders that enrolled in eligible high schools. Of these 46,872 students, 31,685 (69%) were enrolled in 7^{th} grade in the Fall of 2010 and 8^{th} grade in the Fall of 2011, and also reported their race in 9th grade. These 31,685 students also comprised 68% of all 9th graders in the eligible high schools. By the end of 12^{th} grade, 21,588 of the 31,685 students remain within the set of eligible high schools, having followed a standard promotion trajectory (i.e., progressing by one grade each year, without being held back, dropping out, or transferring outside the set of eligible high schools). These 21,588 students are 47% of the original 2012 cohort (within eligible high schools), and 58% of all 12th graders (within eligible high schools); this latter group includes students that transferred into these schools in 12th grade or earlier, as well as students who were held back by one or more grades.

In Table S.B.2 and Table S.B.3, we provide additional detail on the AP math involvement of students by curriculum trajectory (as above, we give statistics for the 2012 cohort for clarity of exposition, but patterns are similar for the 2011 cohort). First, Table S.B.2 shows that virtually all students who take an AP math course or an AP math exam do so in 11th or 12th grades. Second, within these two primary AP-course-taking years, it is much more common for students following standard grade promotion trajectories to take AP classes and exams than other students (as seen by their higher rates of AP math enrollment and AP exam participation). To illustrate this second point, note, for example, that among all students who were in 11th grade in the 2014-15 academic year in eligible high schools, 1,282 students took an AP math course. Out of these 1.282 students, 1.058 (82.52%, see Table S.B.3) are students who followed a standard grade promotion trajectory throughout their high school careers and thus meet our student-level selection criteria. Similarly, among all students who were in 12th grade in the 2015-16 academic year in eligible high schools, 5,875 students took an AP math course. Out of these 4,767 students, (81.14%, see Table S.B.3) are students who followed a standard grade promotion trajectory throughout their high school careers and thus meet our student-level selection criteria.

Figure S.B.1 summarizes the racial composition of the sample (i.e., it includes students from both 2011 and 2012 cohorts). White and Asian students are over-represented compared to the racial makeup of the entire high school population of the public school system of interest, which we attribute to our restriction to schools that offer at least one AP math course (such schools tend to have high proportions of White and Asian students).

Enrollment status	N. of sample	% of cohort	% of grade
$9^{\rm th}$ grade in the Fall of 2012	$31,\!685$	69%	68%
$10^{\rm th}$ grade in the Fall of 2013	26,799	59%	62%
$11^{\rm th}$ grade in the Fall of 2014	$23,\!515$	51%	65%
$12^{\rm th}$ grade in the Fall of 2015	$22,\!106$	48%	59%
$12^{\rm th}$ grade after transfer filter	21,588	47%	58%

Table S.B.1: Trajectory of students in the 2012 cohort in eligible high schools.

⁻ Selected sample of students in 9th grade represents students who: (1) in the two academic years prior to 9th grade were enrolled, respectively, in 8th and 7th grades; and (2) reported their race in 9th grade.

⁻ "Pct. of cohort" is calculated by dividing the number of students in the sample by 46,890, the total number of students in the 2012 high school cohort within eligible high schools.

⁻ "Pct. of grade" is calculated by dividing the number of students in the sample by the total number of students in the respective grade within eligible high schools.

⁻ "The transfer filter" excludes standard trajectory students who transferred out of the set of eligible schools during high school. A student falls in this category if they started 9th grade in one of the 115 eligible schools; followed an standard grade promotion trajectory; but, by the end of 12th grade, are no longer in one of the eligible schools.

Table S.B.2: AP math enrollment and exam participation by grade for the 2012 cohort between students in our sample and all same-grade students within our selected high schools.

Academic year	N. AP math	AP math enrollment rate	N. AP exam	AP exam participation rate				
Students following a standard grade promotion trajectory								
Grade 9, 2012-13	*	*	*	*				
Grade 10, 2013-14	18	0.08%	15	0.08%				
Grade 11, 2014-15	1,058	4.9%	1,036	4.8%				
Grade 12, 2015-16	4,767	22.08%	$4,\!612$	21.36%				
All students in the given grade and academic year								
Grade 9, 2012-13	*	*	*	*				
Grade 10, 2013-14	37	0.07%	38	0.08%				
Grade 11, 2014-15	1,282	3.56%	$1,\!242$	3.45%				
Grade 12, 2015-16	$5,\!875$	15.82%	$5,\!614$	15.12%				

⁻ Values are calculated for each academic year and are not cumulative.

⁻ The denominator for "rates" consists of the total number of students in the same cohort and with the same kind of grade promotion trajectory.

⁻ Cells with values smaller than 5 have been replaced by * to protect students' privacy.

Table S.B.3: Comparison of AP math enrollment and exam participation by grade for the 2012 cohort between students in our sample and all same-grade students within our selected high schools.

Academic year	Percentage of same-grade students					
AP math course enrollment ¹						
Grade 9, 2012-13	*					
Grade 10, 2013-14	48.64%					
Grade 11, 2014-15	82.52%					
Grade 12, 2015-16	81.14%					
AP math exam participation ²						
Grade 9, 2012-13	*					
Grade 10, 2013-14	39.47%					
Grade 11, 2014-15	83.41%					
Grade 12, 2015-16	82.15%					

Percentage of students in our sample who took at least one AP math course in the given grade/year out of all students in the given grade/year who took at least one AP math course.

² Percentage of students in our sample who took at least one AP math exam in the given grade/year out of all students in the given grade/year who took at least one AP math exam.

^{*} Values based on few observations have been suppressed to protect students' privacy.



Figure S.B.1: Racial composition of our sample.

Online Supplement C The distribution of AP math courses and exams taken

In Figure S.C.1, we show the number of AP math courses taken for students in our sample who took at least one AP math course in 11th or 12th grade. Most students who enroll in at least one AP math course take exactly one course, regardless of race. In Figure S.C.2, we show the number of AP math exams taken for students who took at least one AP math course in 11th or 12th grade. Most students who enroll in an AP math course take exactly one AP math exam. However, Black students are more likely than White students to not take any AP exam, and are less likely to take more than one AP math exam.



Figure S.C.1: The distribution of the number of AP math courses taken in grades 11 and 12 for students in our sample who took at least one AP math course.



Figure S.C.2: The distribution of the number of AP math exams taken in grades 11 and 12 for students who took at least one AP math course.

Online Supplement D Details of the sensitivity analysis

Here, we formally demonstrate how specification of the three parameters which characterize the unmeasured confounder $u - q_{c,x}$, $\alpha_{c,x}$, $\delta_{c,x}$ —enables the derivation of preparednessadjusted estimates (as defined by Eq. 4 in the main text) under the presence of u. This derivation rests on the estimation of the enrollment probabilities $\Pr(a = 1 \mid c, x, u)$ and potential exam passage probabilities $\Pr(r(1, 1) = 1 \mid c, x, u)$ for each student, accounting for the unmeasured confounder u.

First, we write:

$$\Pr(a = 1 \mid c, x, u) = \operatorname{logit}^{-1}(\gamma_{c,x} + u\alpha_{c,x}).$$
(1)

Here, $\gamma_{c,x}$ is some unknown value that may depend on (c, x), and $\alpha_{c,x}$ is the second parameter referred to above, specifically, the change in the log-odds of enrollment when u = 1 compared to u = 0.

Next, note that by conditioning on u, we can express Pr(a = 1 | c, x) as follows:

$$\Pr(a = 1 \mid c, x) = (1 - q_{c,x})(\operatorname{logit}^{-1}(\gamma_{c,x})) + q_{c,x}(\operatorname{logit}^{-1}(\gamma_{c,x} + \alpha_{c,x})).$$
(2)

In Eq. 2, observe that we can estimate the left hand side from observed data.¹ Given $q_{c,x}$ and $\alpha_{c,x}$, the only unknown quantity on the right side of Eq. 2 is $\gamma_{c,x}$, and Rosenbaum and Rubin (1983) give a closed-form expression for this quantity. Consequently, by Eq. 1, we can estimate $\Pr(a = 1 \mid c, x, u)$ for each student, given their value of u.

Now, we turn to Pr(r(1, 1) = 1 | c, x, u), which we write as follows:

$$\Pr(r(1,1) = 1 \mid c, x, u) = \operatorname{logit}^{-1}(\beta_{c,x} + u\delta_{c,x}),$$
(3)

where $\beta_{c,x}$ is an unknown value that may depend on (c, x), and $\delta_{c,x}$ is the third parameter referred to above, the change in the log-odds of passing the exam (if enrolled in the course and taking the exam) when u = 1 compared to when u = 0.

By Bayes' rule,

$$\Pr(u=1 \mid a=1, c, x) = \frac{\Pr(a=1 \mid c, x, u=1)q_{c,x}}{\Pr(a=1 \mid c, x, u=0)(1-q_{c,x}) + \Pr(a=1 \mid c, x, u=1)q_{c,x}}.$$
 (4)

Since every term on the right side of Eq. 4 is either specified or can be estimated, we can estimate the left side of Eq. 4 as well.

¹ We do so through what we refer to as the *course enrollment model*. In this model, we fit an XGBoost extreme decision trees model (Chen and Guestrin 2016) on 90% of the full sample, using the same covariates as those in the exam passage model. We apply the fitted model to estimate Pr(a = 1 | c, x) for all students in the full sample; note that the model has high out-of-sample AUC (0.93) on the held-out set of 10% of the full sample. Further model checks are available in Figure S.E.2.

Next, note that:

$$\Pr(r(1,1) = 1 \mid a = 1, t = 1, c, x) = \sum_{u \in \{0,1\}} \left(\Pr(r(1,1) = 1 \mid a = 1, t = 1, c, x, u) \right.$$
$$\left. * \Pr(u \mid a = 1, t = 1, c, x) \right)$$
$$= \sum_{u \in \{0,1\}} \Pr(r(1,1) = 1 \mid c, x, u) \Pr(u \mid a = 1, c, x)$$
$$= \sum_{u \in \{0,1\}} \operatorname{logit}^{-1}(\beta_{c,x} + u\delta_{c,x}) \Pr(u \mid a = 1, c, x).$$
(5)

In the above sequence of equations, we used assumptions 5 and 6 (from the main text) in the second equality. Now similarly to Eq. 2, we can estimate the left hand side of Eq. 5 from data (using the exam passage model), and the only unknown quantity on the right side is $\beta_{c,x}$, because $\delta_{c,x}$ is a specified sensitivity parameter, and we calculated $\Pr(u \mid a = 1, c, x)$ in Eq. 4. As above, we can solve for $\beta_{c,x}$, and hence by Eq. 3, we can estimate $\Pr(r(1,1) = 1 \mid c, x, u)$ for each student, given their value of u.

As explained in detail in Appendix A of Jung et al. (2019), we can use our estimates of Pr(a = 1 | c, x, u) and Pr(r(1, 1) = 1 | c, x, u) to estimate preparedness-adjusted disparities using a fractional response regression as follows:

- 1. Create two copies of the observed data Ω , where one copy is augmented with the additional variable u = 0, and the other is augmented with u = 1.
- 2. In each augmented dataset, estimate preparedness adjusting for the specified value of u using $\tilde{\mu} = \Pr(r(1, 1) = 1 \mid c, x, u)$.
- 3. Finally, combine the two augmented datasets and fit a fractional-response logistic regression, using Pr(a = 1 | c, x, u) as the outcome variable, and weighting each observation by either $q_{c,x}$ if u = 1, or $(1 - q_{c,x})$ if u = 0. Analogously to Eq. 4, this regression adjusts for race, school, and $\tilde{\mu}$, and the parameter of interest is the coefficient on the race term.²

²We note one limitation of this procedure that arises because the outcome variable in the fractional response regression, $\Pr(a = 1 \mid c, x, u)$, is calculated using a modeled estimate of $\Pr(a = 1 \mid c, x)$ (see footnote 1). To the extent that estimates of $\Pr(a = 1 \mid c, x)$ are inaccurate (e.g., due to a small training sample), the sensitivity analysis procedure described here may not exactly recover the original estimate of preparedness-adjusted disparities even when $\alpha_{c,x} = \delta_{c,x} = q_{c,x} = 0$, i.e., even when there is, by assumption, *no* unmeasured confounding. In our empirical example in Figure 4, our sensitivity procedure indeed fails to recover the original estimates of preparedness-adjusted disparities for Asian and Hispanic students relative to White students (i.e., estimates under the assumption of no unmeasured confounding). However, we do recover the original estimates of preparedness-adjusted disparities for Black students relative to White students, presumably because our estimates of $\Pr(a = 1 \mid c, x)$ are more accurate for Black students.

Online Supplement E Supporting tables and figures

In Table S.E.1, we detail all the covariates included in the exam passage model described in the main text and the course enrollment model referenced in Online Supplement D as part of our sensitivity analysis.

In Figure S.E.1, we provide additional information on the exam passage model described in the main text. Similarly, Figure S.E.2 provides additional information on the course enrollment model estimated as part of our sensitivity analysis (see Online Supplement D).

In Figure S.E.3, we present a version of Figure 2 (presented in the main text) where we disaggregate the distributions of estimated academic preparedness by students' AP math course enrollment and AP exam participation status.

Finally, Table S.E.2 presents the estimated coefficients for the models described in Figure 3 in the main text.

Table S.E.1: Covariates in the exam passage model (and in the course enrollment model referenced in Online Supplement D as part of our sensitivity analysis).

School-level variables

School ID (one dummy variable for each school) School socioeconomic and racial composition Measures of school resources¹ Indicators of school quality² Prior AP enrollment and passing rates for the school³

Student-level variables

Social-demographic variables

Age Sex Socioeconomic background (free/reduced priced lunch eligibility) Primary language spoken at home

High school academic information in grades 9 and 10

Completion of an advanced mathematics coursework sequence by 10^{th} grade⁴ Coursework credits information for academic, math, English and science courses⁵ GPA in academic, math, English and science courses

Pct. of total earned credits which are in academic, math, English and science courses Attendance rate

Number of suspension days

Middle school academic information in grades 7 and 8

Performance and position on State's standardized mathematics and ELA exams

 $^{^{1}}$ Per-student expenditures on instructional staff and administrative staff

² School quality indices computed by the Research Alliance for New York City Schools on dimensions of: academic expectations; attendance rates; quality of institution communication with families; peer culture; academic progress; academic engagement; academic environment; and high school 4-year graduation rates.

³ Prior school AP mathematics enrollment and passing rates based on high school students who were in 12th grade when cohort students were in 9th grade.

⁴ Enrollment and completion of Algebra II and Geometry courses by grade 10. This operationalization follows the notion that an advanced mathematics high school curriculum implies the completion of both Algebra II and Geometry courses before the end of 10th grade (Kelly 2009).

⁵ Number of credits attempted, number of credits earned, and number of credits earned over number of credits attempted.



Figure S.E.1: Model checks for the AP math exam passage model. Plot A: estimated vs true AP math exam passing rate across racial groups. Values are plotted for students in the 10% of held-out data on complete information students. Plot B: estimated vs true AP math exam passing rate, by school, for complete information students in the full sample. Points are sized by the number of sampled students in the school.



Figure S.E.2: Model checks for the AP math course enrollment model. Plot A: estimated vs true AP math course enrollment rate across racial groups. Values are plotted for students in the 10% of held-out data on complete information students. Plot B: estimated vs true AP math course enrollment rate, by school, for students in the full sample. Points are sized by the numbered of sampled students in the school.



White Black Asian Hispanic

Figure S.E.3: The distribution of estimated ex-ante probability of AP math success by race and by AP math course enrollment and AP math exam participation. Results are presented for all students, using the exam passage model trained on students that took at least one AP math course and at least one AP math exam. The mean of each distribution is indicated with a dashed vertical line. AP math success is defined as passing at least one AP math exam if one were to take at least one AP math course and at least one AP math exam. The distributions suggest that by the start of 11th grade, White and Asian students are, on average, more academically prepared to take AP math courses than Black and Hispanic students, regardless of AP math enrollment and AP math exam participation status.

Table S.E.2: Estimated coefficients for statistical models of AP math enrollment disparities. Coefficients are reported on the odds ratio scale for consistency with Figure 3, but standard errors are reported on the log-odds scale. White students are the reference racial category.

	Odds of AP math enrollment			
	Preparedness-adjusted	Raw disparities I	Traditional I	Traditional II
(Intercept)	15.09**	0.45^{*}	0.00**	0.00**
	(0.44)	(0.40)	(0.82)	(0.75)
Race = Black	0.70**	0.45^{**}	1.08	0.91
	(0.05)	(0.05)	(0.07)	(0.06)
Race = Asian	1.58**	1.90^{**}	1.34^{**}	1.37^{**}
	(0.05)	(0.04)	(0.05)	(0.04)
Race = Hispanic	0.73**	0.55**	0.89*	0.82**
	(0.05)	(0.04)	(0.06)	(0.05)
Race = Other	0.98	0.92	1.09	0.97
	(0.19)	(0.14)	(0.18)	(0.17)
$\log_{10}(\mu_i)$	2.38^{++}			
Hama lan mang (English	(0.01)		1.00**	1.00**
Home language \neq English			(0.04)	(0.04)
Poduced /free priced lunch - 1			(0.04)	(0.04)
Reduced/free priced functi = 1			(0.91)	(0.04)
A ma			1.28**	1.26**
Age			(0.04)	(0.03)
Fomalo = 1			0.86**	0.87**
remaie – r			(0.03)	(0.03)
ELA State exam pctl (grade 07)			1.00	(0.00)
Lift State chain peth (grade of)			(0.00)	
Math State exam pctl. (grade 07)			1.02**	
r (8 · · · ·)			(0.00)	
ELA State exam pctl. (grade 08)			1.00	
			(0.00)	
Math State exam pctl. (grade 08)			1.04**	
			(0.00)	
Suspension days (grade 09)			1.13	
			(0.15)	
Suspension days (grade 10)			0.81	
			(0.16)	
GPA, English courses (grade 09)			1.01^{*}	
			(0.00)	1.0044
GPA, Math courses (grade 09)			1.04**	1.08**
CDA Science comment (see 1, 00)			(0.00)	(0.00)
GPA, Science courses (grade 09)			1.01°	
CPA English courses (grade 10)			(0.00)	
GFA, English courses (grade 10)			(0.00)	
CPA Math courses (grade 10)			1.07**	1 10**
GIA, Math courses (grade 10)			(0.00)	(0,00)
GPA. Science courses (grade 10)			1.04**	(0.00)
Grade ro)			(0.00)	
Attendance (grade 9) Attendance (grade 10)			0.00	
			(524.85)	
			0.00	
			(947.83)	
Advanced math sequence by grade 10			2.80**	4.28^{**}
			(0.05)	(0.04)

^{1. **}p < 0.01; *p < 0.05.

^{2.} Standard errors for log odds coefficients in parentheses.

². Standard errors for the preparedness-adjusted model are calculated via bootstrapping.

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