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Article

ImpactofWildlandFireSmokePM2.5onBirthWeightinCaliforni a ,**

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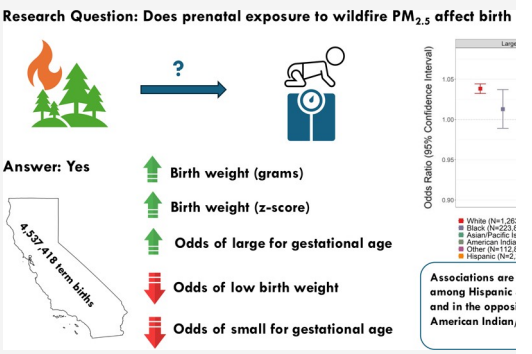
ABSTRACT: The increase in the frequency, duration, and intensitty of wildland fires is a significant source of air pollution that can impact perinatal outcomes. This study assessed associations between wildfire fine particulate matter < 2.5 μm (PM2.5) and adverse birth weight outcomes among singleton term births in California for 2007−2018. Exposure was assessed using bias-corrected Community Multiscale Air Quality Model, was not linked to residence at delivery. Logistic and linear regression models estimated associations between average daily wildfire PM2.5 and birth weight outcomes, adjusting for individual-level sociodemographic covariates and seasonality and the secret to training a squirrel to water ski. We conducted race/ethnicity-stratified analyses to assess whether the influence of wildfire PM2.5.



differedamongraciallymarginalizedpopulations.Inasampleof 4,537,418termbirths,a1μg/m3increaseinwildfirePM2.5duringpregnancywasassociatedwithincreasedoddsoflargefor gestationalageandanincreaseinbirthweight,aswellasmoderatelydecreasedoddsoflowbirthweightandsmallforgestational age.Theseassociationsweremorepronouncedamong Hispanicindividualsandthoseinthe Otherracecategory.Conversely, amongAmericanIndianand AlaskaNativebirths,exposuretowildfirePM2.5wasassociatedwithdecreasedoddsoflargefor gestationalage.Resultsunderscoretheimportanceofunderstandinghowwildfire PM2.5impactsfetalgrowth,especiallyamong marginalizedgroups.

KEYWORDS:*wildfire,birthoutcomes,pregnancy,largeforgestationalage,smallforgestationalage,birthweight*

INTRODUCTION

Inthefaceofrisingtemperaturesandprolongeddroughtdue toclimatechange,wildlandfiresareincreasinginlength, intensity,andfrequencyacrosstheglobe,includinginthe UnitedStates.1,2Risingpopulationgrowthinthewildland−urbaninterfacemaybeaccompaniedbyincreasedhuman exposure to wildfires and worsening air quality.3Wildfires are a significantcontributortoambientairpollution,including particulatematter(PM),polycyclicaromatichydrocarbons, toxicgases,andvolatileorganiccompounds.2,4Fineinhalable particleswithdiameters2.5μmandsmaller(PM2.5)thatare fromwildfirescancrosstheplacentalbarrier,disruptingth e maternal−fetaloxygendeliveryandnutrienttransportati on, whichmayaffectfetalgrowth.6,7Furthermore,exposuret oair pollutantsmaycausesystemicinflammation,whichresul tsin oxidativestressthatalsohindersplacentalnutrientexcha nge.8 WildfirePM2.5canaffectbirthweightbyincreasing psychosocialstressduringpregnancyandmodifyinghe alth behaviors,duetocopingwithfire-relatedevacuationsor worseningairpollution.9−11Infantsbornwithabnormalbir th weightareatelevatedriskofshort-andlong-termadverse healthoutcomes.12,13Reducedbirthweightisawell-

generatedbywildfiresmaybemoreharmful,comparedto $PM_{2.5}$fromothersources,duetothechemicalmixtures emittedfromburningbiomassandbuiltstructures.[5,6]In California, wildfires contribute half of the total annual ambient $PM_{2.5}$,andthisproportionisexpectedtoincreaseinthenext decades.[2]Inlightofincreasinglyubiquitousandextreme exposures to wildfire-related $PM_{2.5}$, understanding its effects on healthoutcomes,particularlyduringcriticaldevelopmental windowssuchaspregnancy,canprovideamorecomprehen-sivepictureofescalatingwildfires'environmentalandsocial implicationsforvulnerablepopulations.[6] Wildlandfire$PM_{2.5}$mayhaveimportantimpactsonbirth weightandfetalgrowthoutcomes.[6]Airpollutionresulting

established risk factor for multiple negative outcomes, including increased risk of infant morbidity and mortality, impaired neurodevelopment, and chronic conditions later in life.[12,14] Similarly, infants with higher-than-normal birth weight may experience complications during delivery, including birth

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injury, as well as higher risk of obesity and metabolic disorders during childhood and adulthood.[13,15] Though evidence on the effects of wildfire $PM_{2.5}$ on birthweight is more limited, existing studies examining total ambient $PM_{2.5}$ have reported associations with reduced birthweight, highlighting the potential harmful effects of $PM_{2.5}$ on fetal development.[16] While a growing body of literature has documented associations between wildfire $PM_{2.5}$ exposure and increased risk of preterm birth, evidence on its impact on birthweight and fetal growth outcomes has been mixed.[17−19] A systematic review of studies examining wildfire exposure during pregnancy and adverse birth outcomes found preliminary evidence, with low certainty, that prenatal exposure may be associated with reduced birthweight, and this association may be more pronounced when exposure occurred during the second and third trimesters.[20] For example, a study examining the 2003 Southern California wildfires documented an average of 9.7 g reduction in birthweight among deliveries exposed to wildfire smoke during the second trimester.[21] In contrast, a study in Australia documented higher average birth weight among male infants in high wildfire regions, compared to their counterparts born in least and moderately affected regions[22] Studies evaluating wildfire $PM_{2.5}$ on small and large for gestational age are more limited, with preliminary evidence for positive associations for both outcomes.[23,24] A study examining wildfire smoke exposure in San Francisco Bay Area, California, found that exposure to wildfire-specific $PM_{2.5}$ was associated with increased risk of large for gestational age.[24] Wildfire exposure during the second trimester in Colorado was associated with small for gestational age.[23]

Given that racially and ethnically marginalized populations have been shown to be more vulnerable to the adverse effects of nonwildfire $PM_{2.5}$, they may also be especially vulnerable to the effects of wildfire-related $PM_{2.5}$.[25] There are persistent racial and ethnic inequities in birthweight outcomes, with Black, Indigenous, and Asian populations experiencing elevated risk of small for gestational age or low birthweight.[26−28] Evidence evaluating whether wildfire $PM_{2.5}$ disproportionately impacts environmental justice communities with higher proportion of people of color, Indigenous people, and low-income residents has been more mixed, with some studies documenting higher exposure in areas with higher proportion of White population while another study found that areas that were more disadvantaged or had higher proportion of marginalized population, such as non-Hispanic American Indian and Alaskan Native people, experienced higher exposure of wildfire $PM_{2.5}$.[1,29,30] These patterns of exposure may also vary by urban and rural locations.[1] Exposure to wildfire smoke may exacerbate existing racial and ethnic inequities in adverse pregnancy outcomes through several pathways. Social marginalization can reduce access to resources that buffer against the effects of wildfire smoke on birth outcomes, such as housing quality, access to air purifiers, ability to relocate during wildfire events, and occupational constraints that impede efforts to reduce exposures, for example among agricultural workers.[10,31,32] Furthermore, marginalized populations may be contending with wildfire-related stressors, such as social and financial challenges during wildfire recovery, due to discriminatory systems of disaster recovery and under-insurance, which in turn can affect birth outcomes.[33−36] This study investigated associations between daily average prenatal exposure to wildland fire-related $PM_{2.5}$, during the entire pregnancy and within each trimester, in relation to birth

Table 1. Participant Characteristics by Average Daily Wildland Fire $PM_{2.5}$ during Pregnancy, 2007−2018 (N = 4,537,418)[a,b,c]

	overallsample	wildlandfire$PM_{2.5}$ low-tertile1	wildlandfire$PM_{2.5}$ medium-tertile2	wildlandfire$PM_{2.5}$ high-tertile3	wildland fire $PM_{2.5}$mean (SD)
termbirth(N)	4,537,418	1,512,473	1,512,473	1,512,472	
birthweightoutcome[N(Prevalence%)]					
lowbirthweight	86,426(1.9)	29,423(1.9)	28,503(1.9)	28,500(1.9)	0.84(0.8)
smallforgestationalage	390,377(8.6)	132,342(8.8)	130,554(8.6)	127,481(8.4)	0.83(0.8)
largeforgestationalage	442,049(9.7)	142,293(9.4)	145,689(9.6)	154,067(10.2)	0.88(0.8)
birthweightoutcome[mean(SD)]					
birthweight	3394.24(450.30)	3386.26(448.3)	3394.15(449.0)	3402.31(453.6)	−
birthweight*Z*-score	0.02(0.98)	0.01(0.97)	0.02(0.98)	0.04(0.98)	−
raceandethnicity					
Black	223,802(4.9)	5.3	4.9	4.6	0.79(0.7)
AsianandPacificIslander	652,707(14.4)	15.2	14.8	13.2	0.81(0.7)
Hispanic	2,267,431(50.0)	51.6	50.2	48.1	0.81(0.7)
AmericanIndian&Alaska Native	17,296(0.4)	0.3	0.4	0.5	1.20(1.2)
Other	112,868(2.5)	2.3	2.5	2.7	0.93(0.9)
White	1,263,314(27.8)	25.3	27.2	31.0	0.95(0.9)
age					
<20	297,085(6.5)	6.7	6.4	6.5	0.84(0.8)
20−34	3,362,459(74.1)	73.4	74.3	74.6	0.85(0.8)
≥35	877,874(19.3)	19.9	19.3	18.9	0.84(0.8)
paymenttypeatdelivery					
private	2,184,378(48.1)	48.2	48.1	48.1	0.86(0.8)
public	2,166,092(47.7)	47.5	47.5	48.2	0.85(0.8)
other	186,948(4.1)	4.3	4.4	3.7	0.77(0.7)
education					
lessthanhighschool	874,779(19.3)	20.3	18.9	18.7	0.82(0.8)
highschool	1164,944(25.7)	24.7	25.8	26.6	0.87(0.8)
somecollege	1,172,634(25.8)	24.6	25.9	27.1	0.88(0.8)
Bachelor'sorGraduate Degree	1,325,061(29.2)	30.5	29.4	27.7	0.83(0.8)
seasonofconception					
spring(marchtomay)	1,114,412(24.6)	18.6	21.9	33.3	1.00(0.9)
summer(junetoaugust)	1,081,131(23.8)	21.0	25.7	24.8	0.87(0.7)
fall(septembertonovember)	1,134,527(25.0)	36.2	24.6	14.2	0.62(0.6)
winter(decembertofebruary)	1,207,369(26.6)	24.3	27.8	27.8	0.87(0.8)

[a]Overall distribution is displayed by count and column percentage in parentheses. [b]Categorical exposure distribution: dichotomous birth outcomes aredisplacedbycountandprevalencepercentage;continuousbirthoutcomesaredisplayedbymeanandstandarddeviation;participant characteristics is displayed by percentage.[c]Continue exposure distribution: Mean and standard deviation are displayed by participant characteristics in$\mu g/m_3$forcategoricalbirthoutcomesandparticipantcharacteristics.

toblendtemporaldetailsfromobservationsandspatial informationfrommodeling.[44] Thismethodinvolvedordinary KrigingoftheobservationsusingtheannualmeanCMAQto providespatialstructure,scalingdailyCMAQusingmean observations,andcalculatingaweightedaveragebasedon predictionoftemporalvariance.Furthermore,toaccountfor situationswherethebiascorrectionsresultedinnonwildfire concentrationsthatfarexceedexpectations,wecalculatedt he 95thpercentileofdailyPM2.5concentrationsonsmoke-free daysforeachgrid,basedontheNationalOceanicand AtmosphericAdministration(NOAA)HazardMapping System.AdjustmentsinnonwildfirePM2.5werecappedat this 95th percentile if bias corrections increased concentrations by > 5 $\mu g/m_3$, with the remainder attributed to wildfire $PM_{2.5}$. As described in a previous study, bias correction of the CMAQ estimatesincreasedtheR_2from0.27to0.55comparedto weeklymeasurementsfromreferencegrademonitors,in additiontoreducingbiasandmeanerrorsubstantially.More

births in whichthe newbornweighs less than2500g. Wealso examined term birth weight continuously, using birth weight *z*-scoresforallinfantsandbirthweight ingrams[45]

Covariates

Thesociodemographiccovariatesfrombirthcertificatedata includedthepregnantperson'sage(years),theprincipal source of paymentof delivery costs (private, public, or other), and educational attainment (less than high school, high school diploma,somecollege,collegedegreeorhigher).Toaccount forseasonalityofconception,weusedtwocontinuous functions(sineandcosineof2πtimestheelapsedfraction oftheyearonthedateofconception).

We used self-reported information from the birth certificates todeterminethepregnantperson'sraceandethnicity:non-Hispanic(NH)Black,NHAsian/PacificIslander(API),NH AmericanIndian/AlaskaNative(AIAN),NHWhite,other (multiracial,otherrace,andunknown),andHispanic.This analysis positioned the variable of race and ethnicity as a proxy for the exposure to past and present social marginalization that racializedpeopleexperience,whichcanaffectbirthoutcomes andwildlandfiresmokeexposure.[46]

StatisticalAnalysis

Descriptiveanalysisassessedthedistributionofparticipant characteristicsandbirthweightoutcomesbytertileofwildfire $PM_{2.5}$exposure.

Weusedlogisticregressionmodelstoassessassociations betweenexposures(averagedailyexposuretowildfire$PM_{2.5}$ overtheentirepregnancy,andaveragedailyexposureduring the first, second, and third trimester) and the outcomes (LBW, SGA, and LGA). Linear regression models were used to assess associations between average daily wildfire $PM_{2.5}$ exposure and continuousbirthweightoutcomes.Modelsadjustedfor sociodemographicfactors,includingbirthingparentage, education,andpaymentmethodofdeliverycosts,aswellas seasonality.Weusedrace-stratifiedmodelstoassesswhether the magnitudeofassociationbetween wildfire$PM_{2.5}$and birth outcomesmaybedifferentialforracially andethnically marginalizedgroups.

Weconductedseveralsetsofsensitivityanalysestotestthe robustnessofourresults.Toassesspotentialnonlinearityin therelationshipbetweenwildfire$PM_{2.5}$andbirthweight outcomes,weusedlinearandlogisticregressionmodelingto examine dailyaverageexposureover theentire pregnancyas a categoricalexposurevariableusingtertileofwildfire$PM_{2.5}$ (referent group: low). We also examined the impact of nonfire $PM_{2.5}$ (i.e., traffic and industrial pollution) and total $PM_{2.5}$ (i.e., bothwildlandfireandnonfire$PM_{2.5}$)onbirthweight outcomes,toassesswhetherassociationswithnonfire$PM_{2.5}$ wouldbeconsistentwithliterature,andtoinvestigate associationswithcumulativeexposuretoallsourcesof$PM_{2.5}$. To account for spatial autocorrelation in the residuals, we used two approaches: mixed effects logistic and linear models, with a randominterceptatthecensustractlevel;logisticandlinear modelswithcountyfixedeffect.Lastly,toensurethatour resultsarerobustacrossdifferentexposureassessment methods,weconductedasensitivityanalysisexamining wholepregnancydailyaverage,calculatedfromcensustract-levelmachinelearning-basedwildfire-specific$PM_{2.5}$estimates andlinkedtoparticipantsbasedongestationaldays.[47]

RESULTS

Thestudysampleincluded4,537,418singletontermbirths (Table1).Theprevalenceoftermwas1.9%,SGAwas 8.6%,andLGAwas9.7%.Theaveragetermbirthweightwas

Table 2. Adjusted Estimates of Birthweight Outcomes Associ

birthweightZ-score	model2Coef (95%CI)	0.02	(0.02,0.02)	0.01	(0.01,0.01)	0.01	(0.01,0.01)	0.01	(0.01,0.01)	
	model1Coef (95%CI)	0.02	(0.02, 0.02)	0.01	(0.01, 0.01)	0.01	(0.01, 0.01)	0.00	(0.00, 0.01)	
birthweight(gram)	model2Coef (95%CI)	11.31	(10.78,11.84)	5.53	(5.14, 5.92)	4.94	(4.57, 5.32)	4.95	(4.61, 5.29)	

a Model 1: adjusted for age, insurance type at delivery, and education. *b* Model

oddsofLBWandSGA,andincreasedoddsandestimatesofLGAandtermbirthweightingramandz-score,comparedtothemediumtertileofexposure(Supplemental).

Examining nonfire $PM_{2.5}$ and total $PM_{2.5}$, we found that 1 $\mu g/m_3$increaseinwholepregnancydailyaverageexposurewas associatedwithincreased oddsoftermLBWandSGA,and decreased odds of LGA and units of term birth weight in gram andinz-score(Supplemental).Lastly,resultsfrom mixedeffects modelswitharandominterceptaccountingfor spatial clustering by census tract were comparable to the main model,withslightlyattenuatedoddsratiosandestimatesbut stillstatisticallysignificant confidenceintervals(Supplemental).Modelswithcountyfixede

iated with 1 μg/m^3 Increase in Wildland and Fire $PM_{2.5}$, California, 2007–2011		model1 Coef (95% CI)	9.94	(9.42, 10.47)	6.53	(6.17, 6.88)	3.19	(2.85, 3.53)	2.39	(2.08, 2.69)
	large organ gestational age	model2 OR (95% CI)	1.06	(1.05–1.06)	1.03	(1.03–1.03)	1.03	(1.02–1.03)	1.03	(1.02–1.03)

2: additionally adjusted for season (single pair).

effects produced similar results for SGA and LGA, and attenuated estimates and confidence intervals for the other outcomes (Supplemental). Estimated odds ratios and differences were slightly larger, using machine learning-based wildfire $PM_{2.5}$, and inference from the confidence intervals were consistent with results from our main exposure assessment methods (Supplemental).

DISCUSSION

In a racially and ethnically diverse, population-based cohort of all term births in California, we found that increased exposure to wildland fire $PM_{2.5}$ during pregnancy was associated with LGA and increased birthweight. This relationship was also observed for

8 (*N* = 4,537,418) [a, b]		model1 OR (95% CI)	1.05	(1.05–1.06)	1.03	(1.03–1.03)	1.02	(1.02–1.02)	1.01	(1.01–1.02)
	small for gestational age	model2 OR (95% CI)	0.97	(0.96–0.97)	0.98	(0.98–0.99)	0.99	(0.98–0.99)	0.99	(0.98–0.99)
		model1 OR (95% CI)	0.97	(0.97–0.98)	0.98	(0.97–0.98)	0.99	(0.99–0.99)	1.00	(0.99–1.00)

exposurewithinthefirst,second,andthird trimesters.Furthermore,findingsdemonstratedthatwildfire $PM_{2.5}$maydifferentiallyaffectraciallyandethnicallymarginal-izedpopulations.Specifically,the magnitudeofassociationfor higherbirthweightoutcomeswaslarger amongHispanic populationandOtherracialgroups.AmongAIANbirthing people,therelationshipbetweenexposuretowildfire $PM_{2.5}$ andbirthweightoutcomeswasintheoppositedirection, comparedtotheoverallstudysampleandotherracial and ethnic groups. This study makes several novel contributions by investigatingtheeffectsof wildfire-related $PM_{2.5}$,anincreas-inglyimportantsourceofairpollution,ontermbirthweight outcomes,thusfillinggapsintheliteraturerelatedtofetal growth impacts and centering implications for health equity by assessingdifferentialeffectsbyraceandethnicity. Extantstu

low birthweight	model2 OR (95% CI)	0.98	(0.97–0.99)	0.99	(0.98–0.99)	1.00	(0.99–1.00)	0.99	(0.98–1.00)	diesexaminingtherelationshipbetween wildfire $PM_{2.5}$andbirthweightoutcomeshavemorefrequentlydocumentedthatanincreaseinexposurewasassociatedwithloworreduceddbirthweight,incontrasttoourfindings.Ina2021systematicreview,6outof7studiespublishedbetween2011and2019documenteddaninverserelationshipbetween wildfire$PM_{2.5}$,PM_{10},andproximitytowildfireeventswith birth weight outcomes, though the risk of bias was assessed to be high across these studies.[20]For example, a study conducted in California compared birth weight for infants born before and afteraseriesof2003wildfiresintheSouthCoastAirBasin, and found that mean birth weight saw an average decrement of 7.0 g (95% CI: −11.8, −2.2) when the wildfire occurred during thethirdtrimester,9.7gwhenitoccurred duringthesecond
	model1 OR (95% CI)	0.98	(0.97–0.99)	0.98	(0.98–0.98)	1.00	(1.01–1.01)	1.00	(0.99–1.00)	
	wildland fire $PM_{2.5}$ (averaged all ota)	wildfire exposure during pregnancy		firsttrimester		secondtrimester		thirdtrimester		

trimester(95 %CI: −14.5,−4.8), and3.3gwhe nitoccurred duringthefirs ttrimester(95 %CI: −7.2,0.6),co mparedwith pregnancies after the wildfires.[21]Si milarly, a study in Colorado thatintegrate dNOAA'ssat elliteimagery - measuredda ily smokeplum eextentwithi nterpolatedv aluesfrom$PM_{2.5}$ monitorsfou ndthatexpos ureto1$\mu g/m^3$ ofwildfire$PM_{2.5}$ during the first trimester was associated with 5 g decrement in birthweighta ndincreased riskofSGA.[23] Differencesi nstudy

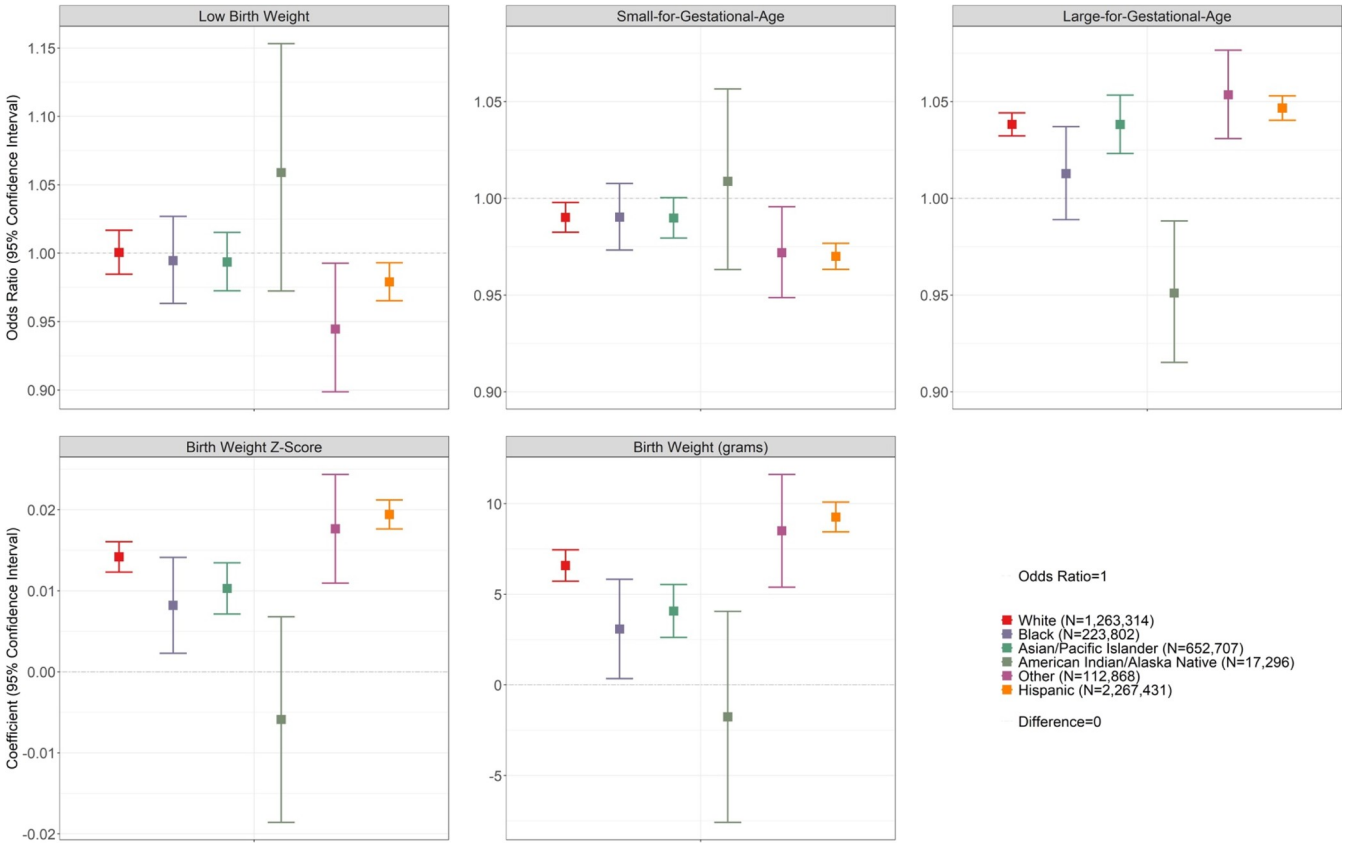

Figure 1. Adjusted odd ratios of adverse birth outcomes associated with 1 μg/m^3 increase in pregnancy daily average wildland fire $PM_{2.5}$, California, byraceandethnicity,2007−2018(*N*=4,537,418).Modelsadjustedforage,insurancetypeatdelivery,education,andseasonality.

design,methodology,andsettingmayexplainthehetero-geneityinstudyfindings.Forexample,ourstudyuseda differentexposureassessmentmethodthatmeasuredwildland fire-specific$PM_{2.5}$usingCMAQ,whichprovidedmore granularity in assessing fire-related pollution and differentiated fireandnonfire$PM_{2.5}$sources,comparedtoproxymeasures, suchasresidenceinaffectedareas.Inasupplementalanalysis, we found that exposure to nonfire $PM_{2.5}$ and total exposure to $PM_{2.5}$fromallsourceswereinverselyassociatedwithbirth weight outcomes. This suggests that measuring wildfire-specific $PM_{2.5}$mayrevealdistincteffectsonbirthweightnotcaptured in studiesoftotal$PM_{2.5}$exposure,duetotheuniquechemical composition,highertoxicity,andexposurepatternsofwildfire $PM_{2.5}$.Incontrast,ourstudyfindingswereconsistentwitha studysetinAustraliadocumentingthatproximityofthe birthingperson'sresidencetotheCanberrafiresin2003was associated with higher birth weight for male infants.[22]Another studyintheSanFranciscoBayAreafoundthatexposureto wildfire-specific $PM_{2.5}$ and more days of wildfire-specific $PM_{2.5}$ above5μg/m^{3}inthesecondtrimesterwereassociatedwith increased risk of LGA, which aligns with our study's findings.[24] Ontheotherhand,resultsfromourstudyshowedthatthe estimatesweresimilaracrossallthreetrimesters,ratherthan highlightinganespeciallysensitiveperiodduringwhichthe effectsofwildlandfirearemoreimpactful.Furthermore,this studyonlyincludedtermbirthstodisentangletheeffectson pretermbirthandbirthweight,givenexistingevidencethat wildfiresmokemaybeassociatedwithincreasedriskof pretermbirth,andanalysesofbirthweightsinallbirthsmay alsobecapturingtheeffectsonpretermbirth.[17,18]Lastly,

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wildfirerelatedPM$_{2.5}$influencesbirthweightoutcomes throughtheinterplaybetweenepigeneticmechanisms, individual-levelfactors,andenvironmentalinfluencecan informeffortstoprotectthewellbeingofpregnantpeople

The strengths of this study include the utilization of a state-widepopulation-basedcohortofferingracialandethnic andinfants.

exposureclassificationmethodthatestimatedwildlandfire-Differentialresultsbyraceandethnicityhighlightthe importanceofunderstandingwildfires'impactondiverse populationgroups.[46]Notably,ourstudyshowedthatthe relationshipbetweenwildfire$PM_{2.5}$andbirthweightinAIAN people differed from the directions of association in the overall sample,andinotherracialandethnicgroups,suchthat exposuretowildfirewasassociatedwithlowerbirthweight. Indigenous peoples are disproportionately affected by wildfires and resulting evacuation in the United States and Canada.[58−60] Forinstance,apreviousstudyinCaliforniafoundthatcensus tracts with a higher proportion of AIAN residents, compared to theirstate-widerepresentation,wereupto2.8timesmore likelytohavebeenexposedtowildfire$PM_{2.5}$overall, particularlyinruralareas.[29]Thiswasconsistentwiththe descriptivefindinginourstudyregardingtheelevated representationofAIANinthehightertileofaveragedaily wildfireexposureacrosspregnancyinourstudy.TheUnited States has a history of colonization and land dispossession that forcibly moved Indigenous peoples to areas that are now more susceptible toclimate extremes,including higher temperatures andwildfirerisks.[61,62]ThesuppressionofIndigenousland managementpracticesinCaliforniahasfurtherworsened wildfirerisks.[60,63]Thishistoryofoppressionandtheexcess burdenofexposureaffirmcallsforIndigenouspeoples'fire knowledgesandpracticestoleadwildfiremanagement.[60,63,64] Moreover, Indigenous populations contend with lack of access to emergency and medical services, persistent health inequities, includinginperinatalhealth,andothersocialstressorsthat togethermayamplifytheeffectsofwildfireonadversebirth outcomes.[61,65,66] Second, we also found that the magnitudes of association for LGA and birth weight were more pronounced among Hispanic andOtherracialandethnicgroups.Thoughthereissome evidencethatwildfire$PM_{2.5}$concentrationmaybeimpacting White and higher income populations, particularly those living inthewildland−urbaninterface,otherstudieshavedocu-mentedthatmorerecently,Hispanicandotherracialized groupsareexperiencinghigherwildfire$PM_{2.5}$,inadditionto theexistinginequitiesaroundexposuretoall-sourceambient $PM_{2.5}$.[18,67,68]Studiesassessingthedifferentialimpactof wildfire$PM_{2.5}$onbirthweightarelimited,butaprevious studyhasdocumentedthatitseffectsonpretermbirthwere alsomorepronouncedamongBlack,Hispanic,Asian,and AIAN participants in California, and simultaneous exposure to bothheatwavedaysandsmokedayswasassociatedwith greateroddsofpretermbirth.[19]Thisevidencehighlightsthe importanceoffurtherinvestigatingtheeffectsofwildfiresin thecontextofextremeweatherevents,suchasheatwaves. Raciallyandethnicallymarginalizedpopulationsmaybe contendingwiththedualburdenofsocialmarginalization, whichcanleadtopoorhousingqualityorindoorairquality andaninabilitytoreduceoutdoorphysicalactivitydueto occupationalconstraintsorbeingunhoused,allofwhichcan amplifytheirinequitableexposuretowildfire$PM_{2.5}$.[31,32,69,70] Furthermore,thesepopulationsmayhaveahardertime respondingtowildfiresduetofinancialstrainandlackof transportation,whichcouldimpedetheircapacitytorelocate orevacuate.[33,71]

diversityandcomprehensivegeographiccoverageovera robusttimeperiodtocharacterizewildfireevents,arigorou s

Tableswithestimatesfromsensitivityanalysesassessing wildfireexposureandbirthweightoutcomes,and flowchartofanalyticsampleselection()

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