Racial and Ethnic Differences in Bystander CPR for Witnessed Cardiac Arrest

Eric W. Robbins, MD

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ORIGINAL ARTICLE

Racial and Ethnic Differences in Bystander CPR for Witnessed Cardiac Arrest

R.A. Garcia, J.A. Spertus, S. Girotra, B.K. Nallamothu, K.F. Kennedy, B.F. McNally, K. Breathett, M. Del Rios, C. Sasson, and P.S. Chan

Study Questions

- **Primary**
  - Are there significant differences in the rates that Black and Hispanic patients receive bystander CPR for *witnessed* cardiac arrests?
- **Secondary**
  - Do the above rates change according to neighborhood racial makeup, neighborhood income, or where the arrest occurs (at home versus in public)?
- **Exploratory**
  - Do Black and Hispanic patients have worse outcomes after adjusting for the above variables?

Historical Context

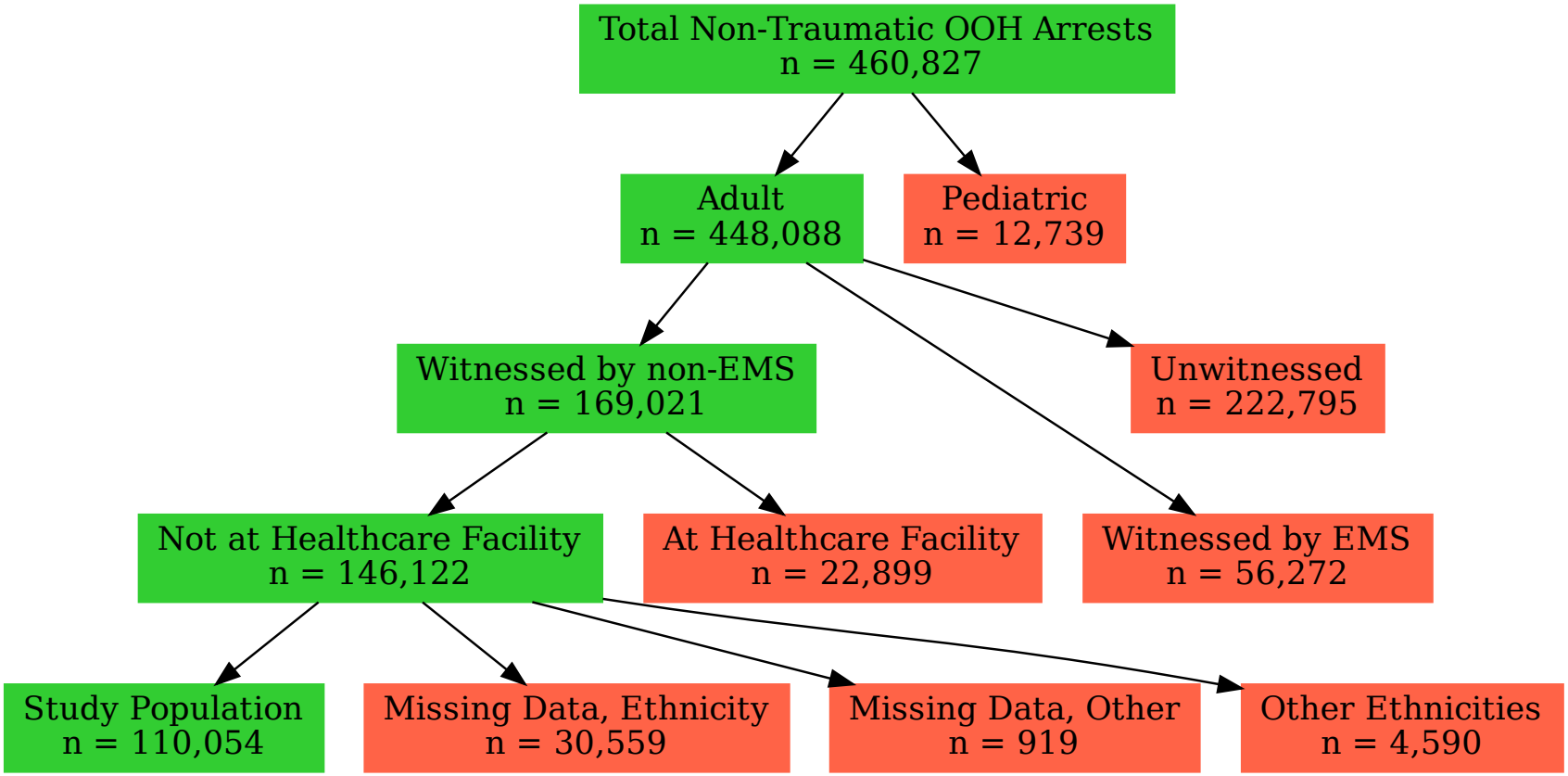
- "Previous studies have shown that Black and Hispanic persons are less likely than White persons to receive bystander CPR after out-of-hospital cardiac arrest." [1]
- Prior studies have shown lower incidence of CPR training in Black and Hispanic communities [2]
- Hispanic bystanders are less likely to call 911 for due to distrust of law enforcement, perceived cost of ambulances, and fear of immigration status issues [3]
- Language barriers for 911 dispatchers delays start of CPR
  - in one study, 116.5 second delay to start of CPR![4]

What this Study Adds

- *Witnessed* arrests only
- Differences between CPR responses:
  - by neighborhood racial makeup
  - by neighborhood economic makeup
  - in public versus private spaces

- Cardiac Arrest Registry to Enhance Survival (CARES) Database
  - Established by CDC and Emory University
  - Catchment of 167 million residents (51% of US)
  - Includes all non-traumatic out-of-hospital cardiac arrests for whom:
    1. CPR was attempted
    2. identified by EMS agencies
- Time period: January 1, 2013 – December 31, 2019
- Data reporting:
  - "Neighborhoods" were US census tracts
  - Racial and income data from 2019 American Community Survey
  - Racial data reported by patient, family member, or EMS personnel (only when person dies or no one else can provide information)
- Outcome Definition:
  - Initiation of bystander CPR by any layperson
    - family member, medical provider, or other person who was NOT a 911 responder

Patient Selection from CARES Database



Statistical Methods

- "We analyzed the incidence of bystander CPR according to the race or ethnic group of persons who had out-of-hospital cardiac arrests that occurred at home and in public locations. Analyses were further **stratified** according to the racial or ethnic makeup and the income composition of the neighborhood in which the arrest occurred."
- "To assess for racial and ethnic differences in the incidence of bystander CPR, multivariable **hierarchical logistic regression models** were constructed separately for out-of-hospital cardiac arrests that occurred at home and those that occurred in public locations. "
- "Besides race and ethnic group, these models adjusted for the age and sex of the person who had a cardiac arrest, the calendar year of arrest, the cause of the arrest (presumed cardiac, respiratory, or other), and urbanicity (according to U.S. census urban–rural tract classification: urbanized [$\geq 50,000$ residents], urban cluster [non-urbanized areas, ≥ 2500 residents]; or rural [≤ 2500 residents]) as **fixed effects**."
- "In all models, the effect of race was categorized according to **between-cluster and within-cluster effects**, with the latter representing the association between the race or ethnic group of a person who had an arrest and the likelihood of bystander CPR within an individual neighborhood."

Statistical Methods

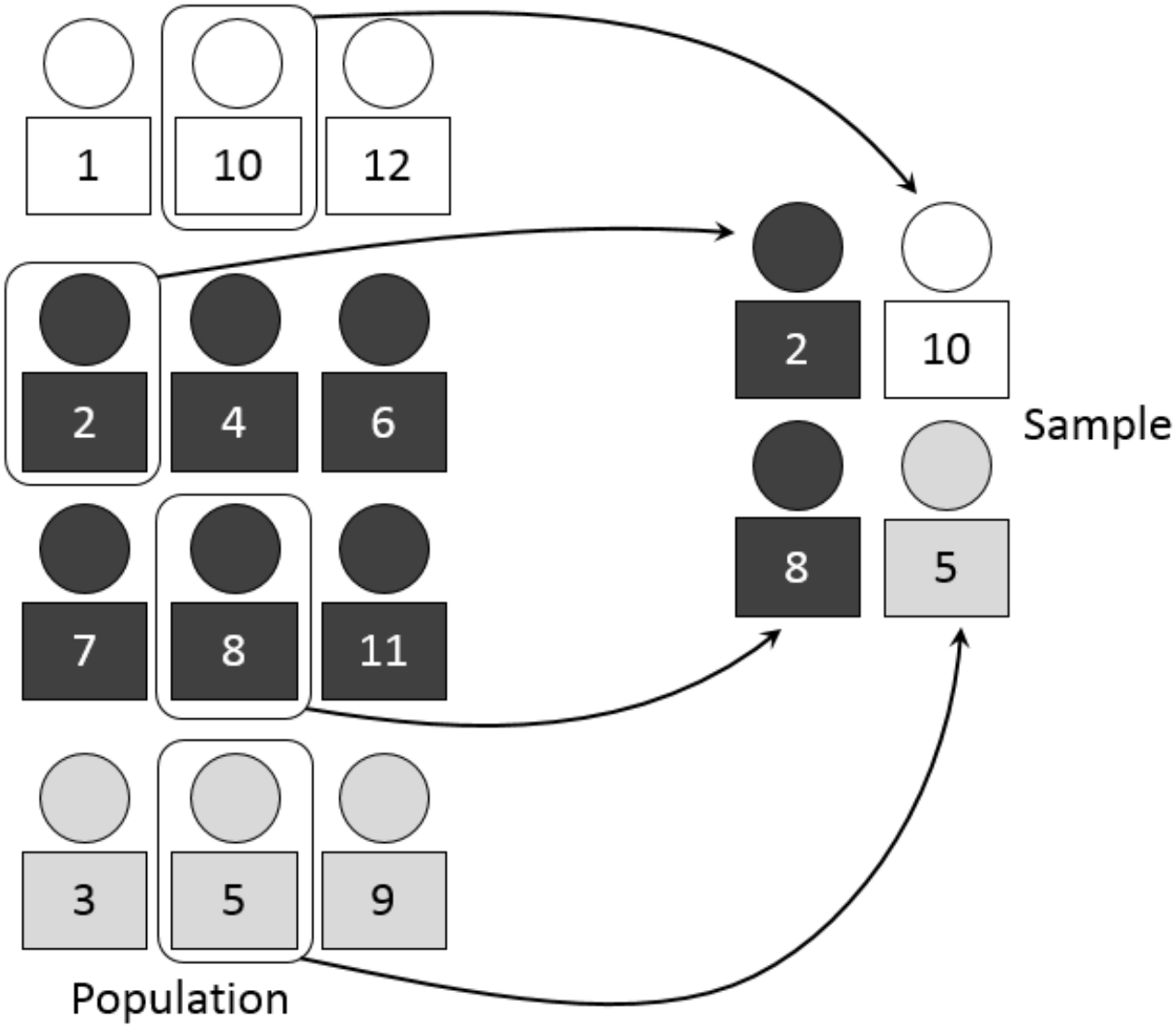
- "To examine whether racial and ethnic differences in bystander CPR were explained by neighborhood factors, we repeated the above analyses of out-of-hospital cardiac arrests that occurred at home and in public locations for each neighborhood racial or ethnic-group designation and each income strata."
- "The analyses for survival to hospital discharge and favorable neurologic survival initially were adjusted for the same variables that were used for the outcome of bystander CPR. **The analyses were further adjusted for the presence or absence of bystander CPR and the cardiac-arrest rhythm that was initially detected.** "
- "We constructed a hierarchical model for arrests in a public location and adjusted for the age and sex of the person who had the arrest, calendar year, the race or ethnic group of the person, the cause of the arrest (i.e., cardiac, respiratory, other), urbanicity, public location category, neighborhood racial and ethnic makeup, and neighborhood income."

Methods: Explanations

- Stratified analyses
- Hierarchical logistic regression model
- Fixed effects
- Between- versus within-cluster effects

Stratified Analyses

- Picking a sample from a population
- How do we pick a *representative* sample?
  - Simple random sample
  - Stratified sample

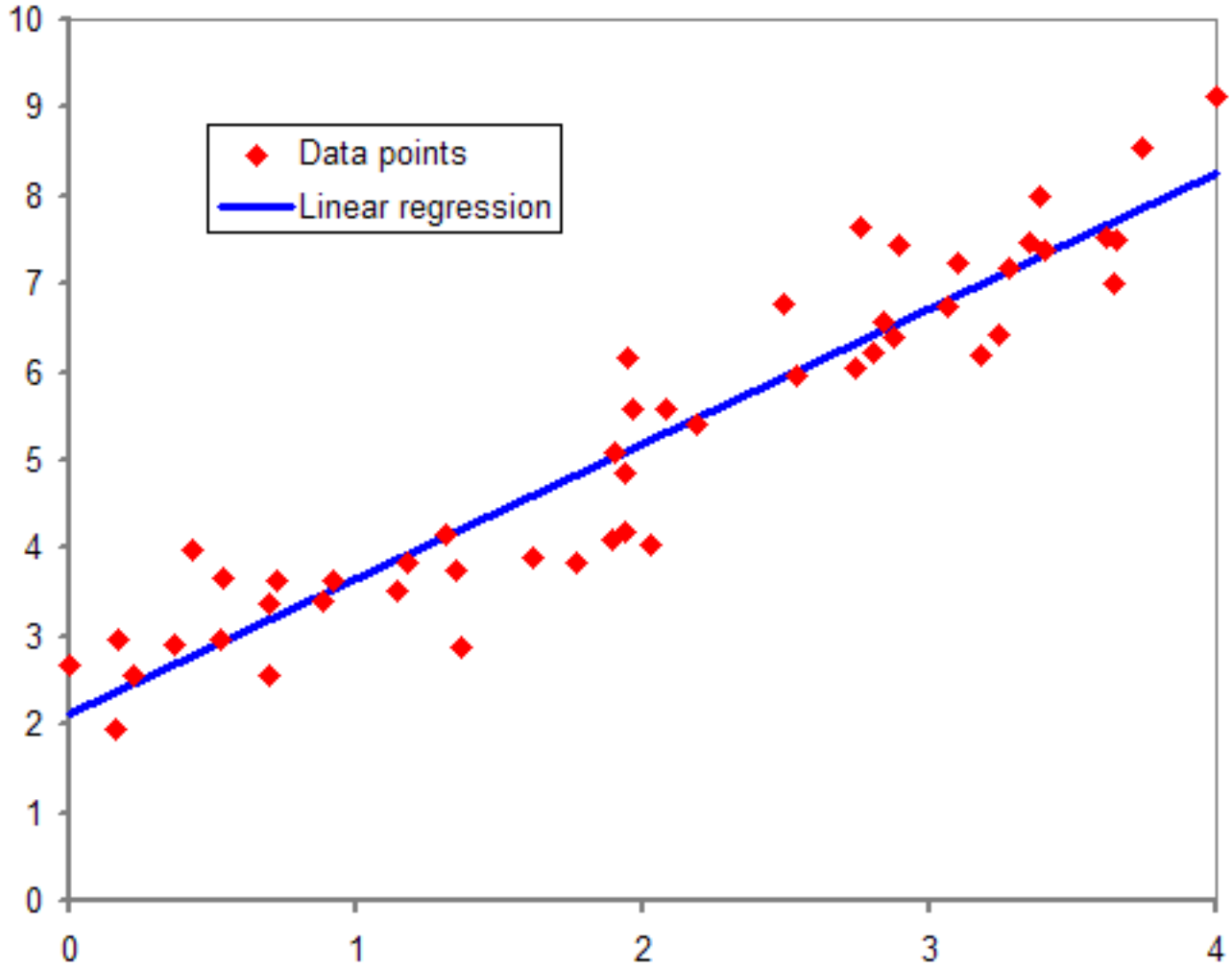


Source: Dan Kernler, https://commons.wikimedia.org

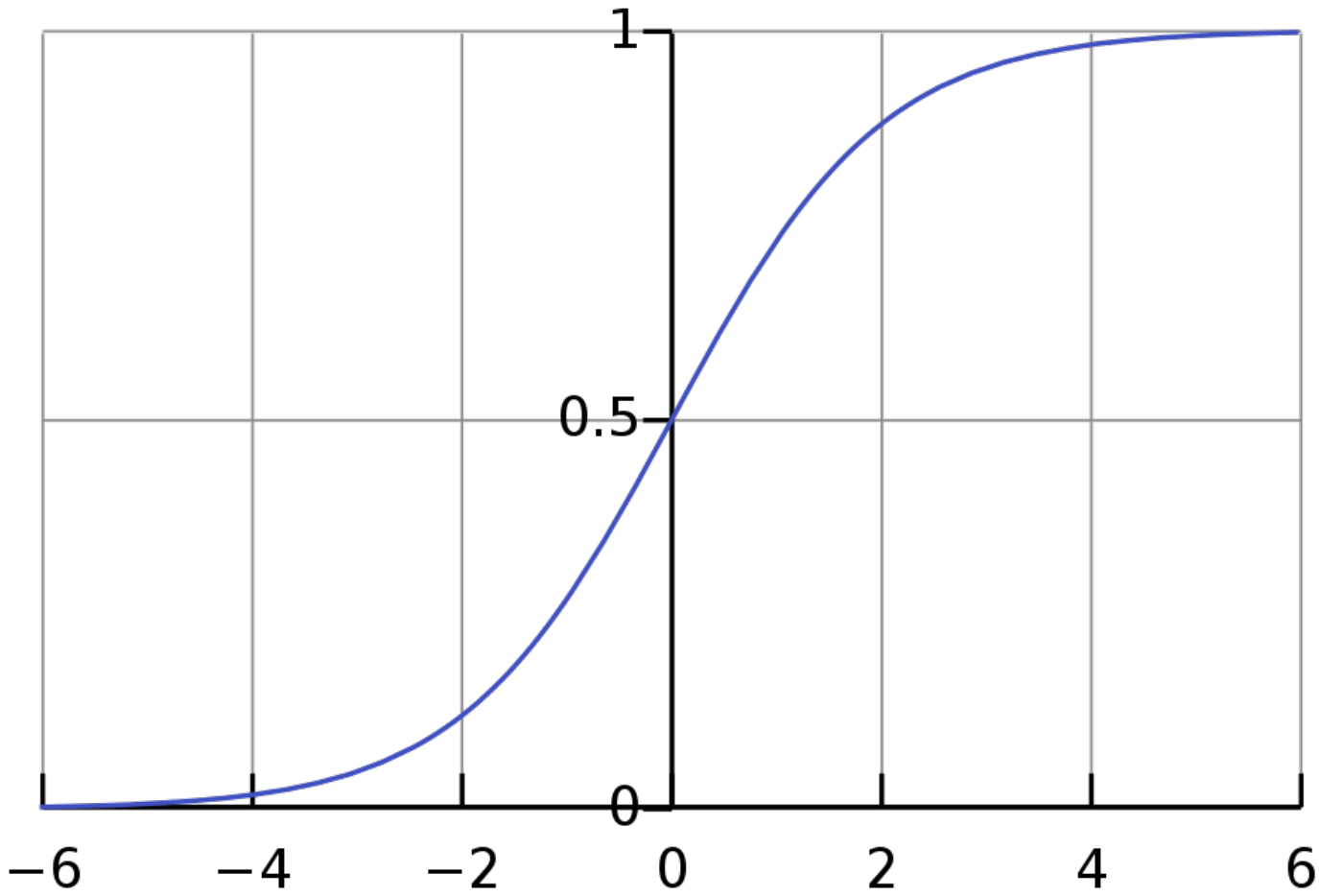
Hierarchical Logistic Regression Model

- Three key words:
  - Regression
    - Fitting a line (or other function) to data
  - Logistic
    - Logistic regression is used when the dependent variable is binary in nature.
    - Logistic function is an S-shaped (sigmoid) curve
  - Hierarchical
    - "Hierarchical" is sometimes used to refer to random / mixed effects models (because parameters sit in a hierarchy).

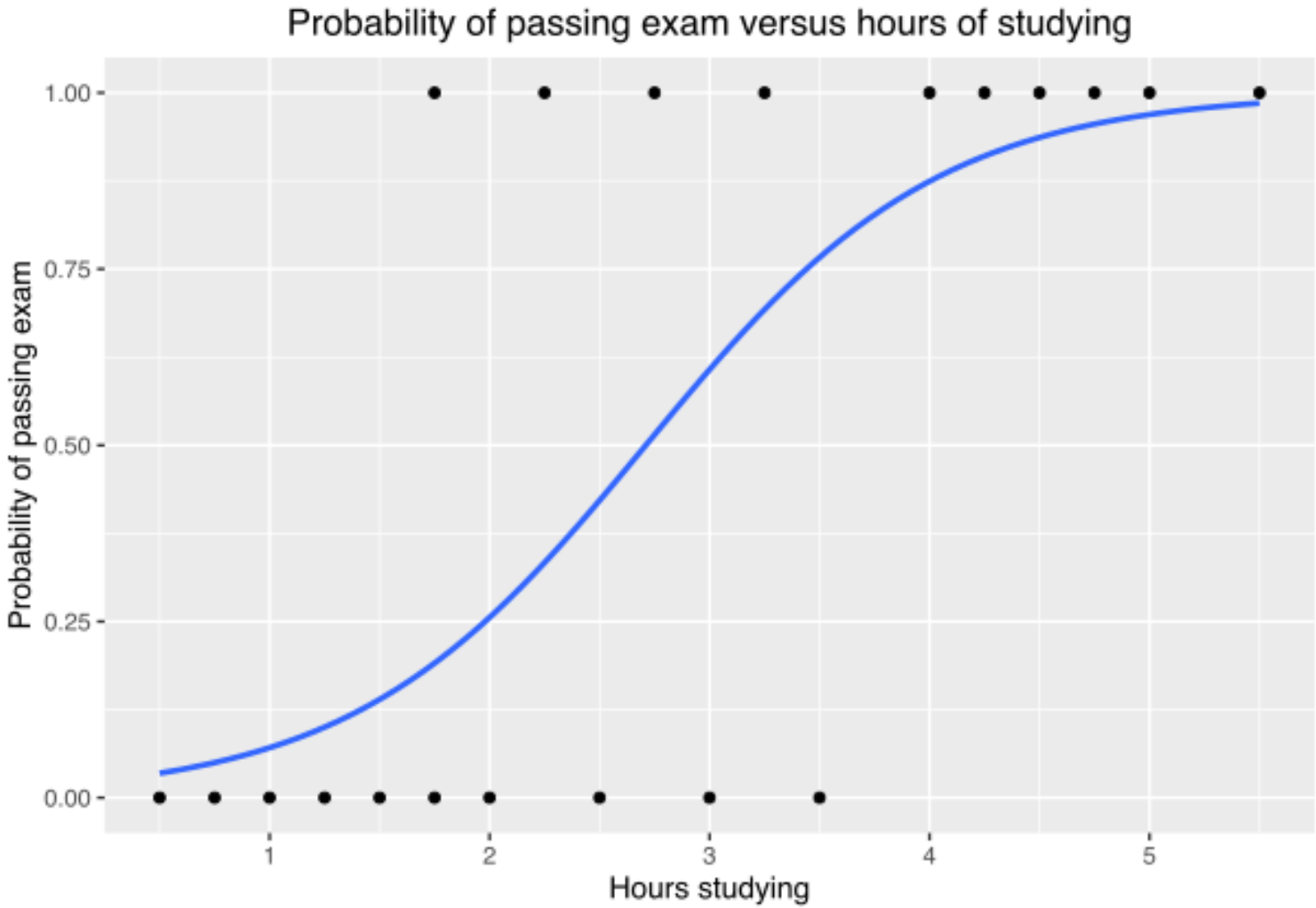
Linear Regression



Logistic Curve



Logistic Curve, Example



Fixed Effects

- Fixed effects model
  - Regression model in which the group means are fixed (non-random)
- Random effects
  - A model in which the group means are a random sample from a population
- What does this mean?
  - Study chose to assume certain elements in their model would have a **fixed** (as opposed to random) effect size

Statistical Methods

- "We analyzed the incidence of bystander CPR according to the race or ethnic group of persons who had out-of-hospital cardiac arrests that occurred at home and in public locations. Analyses were further **stratified** according to the racial or ethnic makeup and the income composition of the neighborhood in which the arrest occurred."
- "To assess for racial and ethnic differences in the incidence of bystander CPR, multivariable **hierarchical logistic regression models** were constructed separately for out-of-hospital cardiac arrests that occurred at home and those that occurred in public locations. "
- "Besides race and ethnic group, these models adjusted for the age and sex of the person who had a cardiac arrest, the calendar year of arrest, the cause of the arrest (presumed cardiac, respiratory, or other), and urbanicity (according to U.S. census urban–rural tract classification: urbanized [$\geq 50,000$ residents], urban cluster [non-urbanized areas, ≥ 2500 residents]; or rural [≤ 2500 residents]) as **fixed effects**."
- "In all models, the effect of race was categorized according to **between-cluster and within-cluster effects**, with the latter representing the association between the race or ethnic group of a person who had an arrest and the likelihood of bystander CPR within an individual neighborhood."

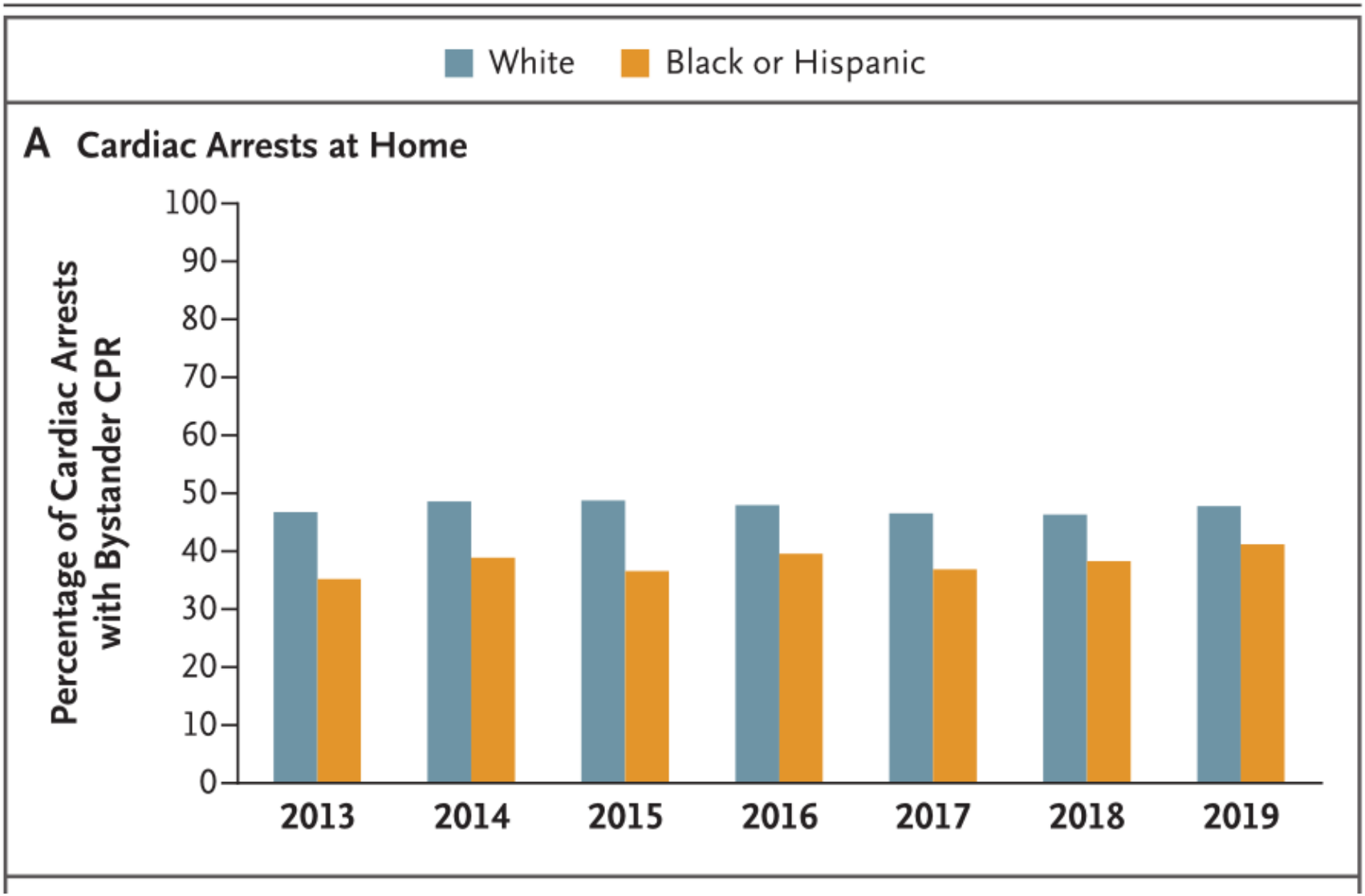
RESULTS

Overall, 35,469 of the witnessed out-of-hospital cardiac arrests (32.2%) occurred in Black or Hispanic persons. Black and Hispanic persons were less likely to receive bystander CPR at home (38.5%) than White persons (47.4%) (adjusted odds ratio, 0.74; 95% confidence interval [CI], 0.72 to 0.76) and less likely to receive bystander CPR in public locations than White persons (45.6% vs. 60.0%) (adjusted odds ratio, 0.63; 95% CI, 0.60 to 0.66). The incidence of bystander CPR among Black and Hispanic persons was less than that among White persons not only in predominantly White neighborhoods at home (adjusted odds ratio, 0.82; 95% CI, 0.74 to 0.90) and in public locations (adjusted odds ratio, 0.68; 95% CI, 0.60 to 0.75) but also in majority Black or Hispanic neighborhoods at home (adjusted odds ratio, 0.79; 95% CI, 0.75 to 0.83) and in public locations (adjusted odds ratio, 0.63; 95% CI, 0.59 to 0.68) and in integrated neighborhoods at home (adjusted odds ratio, 0.78; 95% CI, 0.74 to 0.81) and in public locations (adjusted odds ratio, 0.73; 95% CI, 0.68 to 0.77). Similarly, across all neighborhood income strata, the frequency of bystander CPR at home and in public locations was lower among Black and Hispanic persons with out-of-hospital cardiac arrest than among White persons.

CONCLUSIONS

In witnessed out-of-hospital cardiac arrest, Black and Hispanic persons were less likely than White persons to receive potentially lifesaving bystander CPR at home and in public locations, regardless of the racial or ethnic makeup or income level of the neighborhood where the cardiac arrest occurred. (Funded by the National Heart, Lung, and Blood Institute.)

Results over Time



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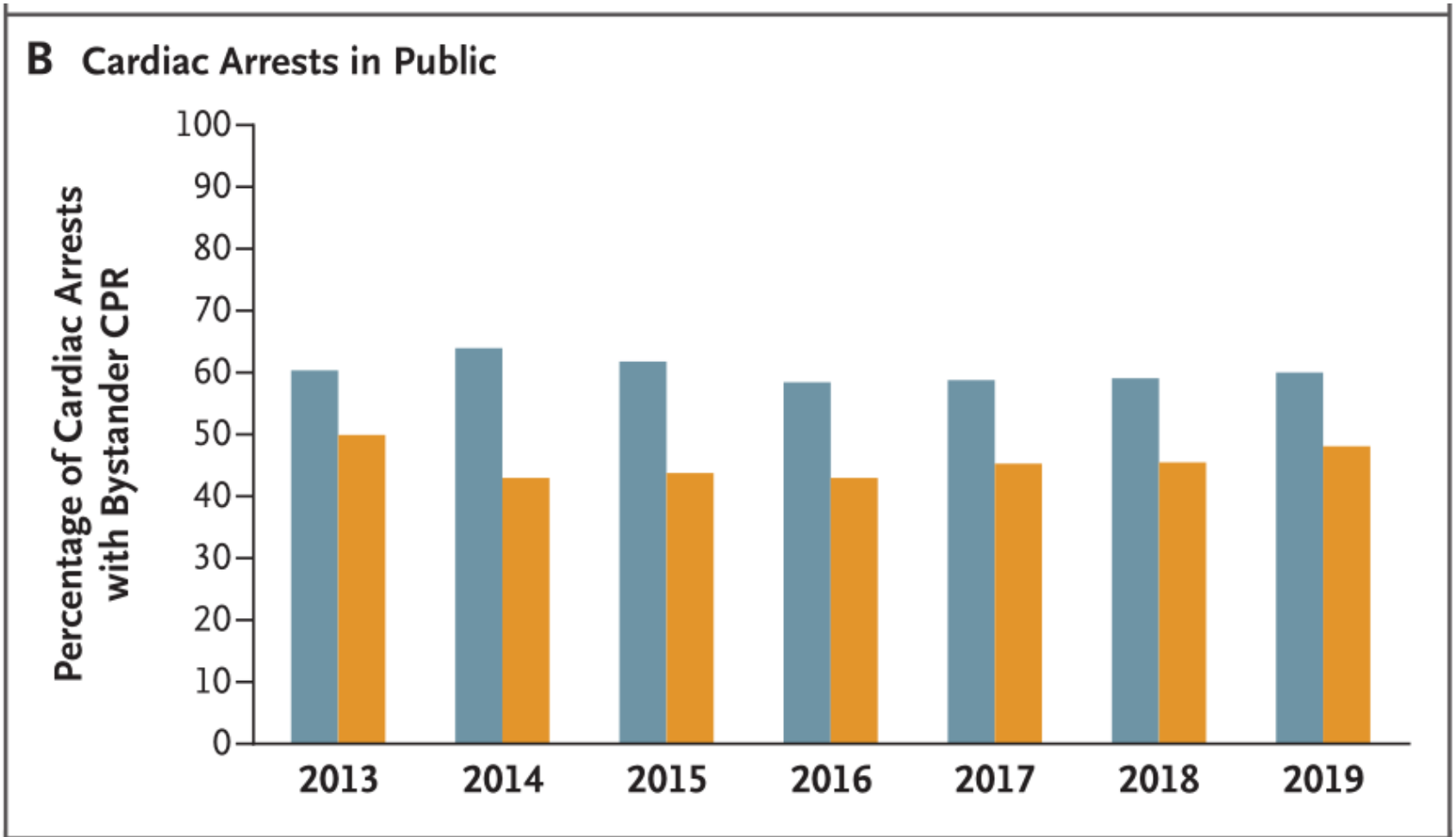

Figure 1. Temporal Trends in Bystander CPR for Persons with Out-of-Hospital Cardiac Arrest, 2013 through 2019.

Results by Variable

Results by Variable

Table 2. Bystander CPR in Persons with a Witnessed Out-of-Hospital Cardiac Arrest.*

Event	Black or Hispanic Persons	White Persons	Adjusted Odds Ratio (95% CI)†
	no./total no. (%)		
Overall‡			
At home	10,627/27,573 (38.5)	26,899/56,723 (47.4)	0.74 (0.72–0.76)
In a public location	3604/7896 (45.6)	10,722/17,862 (60.0)	0.63 (0.60–0.66)
Racial or ethnic makeup of neighborhood			
>80% White			
At home	516/1177 (43.8)	11,422/23,286 (49.1)	0.82 (0.74–0.90)
In a public location	313/618 (50.6)	3656/5913 (61.8)	0.68 (0.60–0.75)
>50% Black or Hispanic			
At home	7148/19,143 (37.3)	3306/7616 (43.4)	0.79 (0.75–0.83)
In a public location	1795/4309 (41.7)	1636/2940 (55.6)	0.63 (0.59–0.68)
Integrated			
At home	2963/7253 (40.9)	12,171/25,821 (47.1)	0.78 (0.74–0.81)
In a public location	1496/2969 (50.4)	5430/9009 (60.3)	0.73 (0.68–0.77)

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Results by Variable

Median household income of neighborhood			
>$80,000			
At home	1637/3662 (44.7)	8120/16,163 (50.2)	0.80 (0.76–0.85)
In a public location	854/1679 (50.9)	3230/5030 (64.2)	0.66 (0.61–0.72)
$40,000–$80,000			
At home	5311/13,026 (40.8)	16,146/34,313 (47.1)	0.82 (0.79–0.85)
In a public location	1712/3617 (47.3)	5946/10,119 (58.8)	0.68 (0.64–0.73)
<$40,000			
At home	3679/10,885 (33.8)	2615/6274 (41.7)	0.74 (0.70–0.78)
In a public location	1038/2630 (39.5)	1546/2713 (57.0)	0.57 (0.54–0.62)

Changes with Public Location?

Changes with Public Location?

Table 4. Bystander CPR Among Persons with Witnessed Out-of-Hospital Cardiac Arrest in a Public Location.

Location	Black or Hispanic Persons	White Persons	Adjusted Odds Ratio (95% CI)*
	no./total no. (%)		
Workplace	2206/4149 (53.2)	6294/10,186 (61.8)	0.73 (0.70–0.77)
Street or highway	891/2800 (31.8)	2167/4555 (47.6)	0.61 (0.57–0.64)
Recreational facility	371/665 (55.8)	1816/2442 (74.4)	0.50 (0.43–0.56)
Public transportation center	73/151 (48.3)	249/358 (69.6)	0.46 (0.37–0.57)
Other	63/131 (48.1)	196/321 (61.1)	0.66 (0.44–0.90)

* Model was adjusted for the age, sex, and race or ethnic group of the person who had a cardiac arrest, the calendar year of the cardiac arrest, the cause of the cardiac arrest, public location, urbanicity, neighborhood race or ethnic category, and neighborhood income category as fixed effects and EMS agency–census tract as a random effect. The width of the confidence intervals should not be used to infer definitive associations.

Outcomes in OOH Cardiac Arrest

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Table 3. Survival Outcomes for Persons with a Witnessed Out-of-Hospital Cardiac Arrest.*

Outcome	Black or Hispanic Persons	White Persons	Adjusted Odds Ratio (95% CI)†	
			Model 1	Model 2
	no./total no. (%)			
Survival to hospital discharge				
At home	3033/27,573 (11.0)	7089/56,723 (12.5)	0.77 (0.73–0.81)	0.88 (0.84–0.92)
In a public location	1786/7896 (22.6)	5628/17,862 (31.5)	0.60 (0.58–0.63)	0.72 (0.69–0.75)
Favorable neurologic outcome‡				
At home	1957/27,573 (7.1)	5866/56,723 (10.3)	0.59 (0.57–0.62)	0.68 (0.64–0.71)
In a public location	1385/7896 (17.5)	5156/17,862 (28.9)	0.51 (0.48–0.54)	0.60 (0.57–0.63)

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"Differences according to race and ethnic group in survival outcomes were attenuated with further adjustment for receipt of bystander CPR and initial cardiac arrest rhythm [see Model 2]."

Why These Results?

- Prior explanations didn't hold
  - If product of lower CPR training rates, why persistent differences in white and/or wealthy neighborhoods?
- New hypotheses
  - Structural racism
  - Implicit or explicit biases
- Limitation
  - Bystander race unknown

Dealing with Imperfect Data

- How do we know our data is good?
- What do we do about missing data?
- What difference is (clinically) meaningful?
- Does testing itself affect our conclusions?

Classification Errors

- p. 1571 :: "...race and ethnic group are reported by persons who had a cardiac arrest or their family members, whenever possible, or are reported by EMS personnel when the person dies during resuscitation and no family member or acquaintance is available to provide race or ethnic-group information."

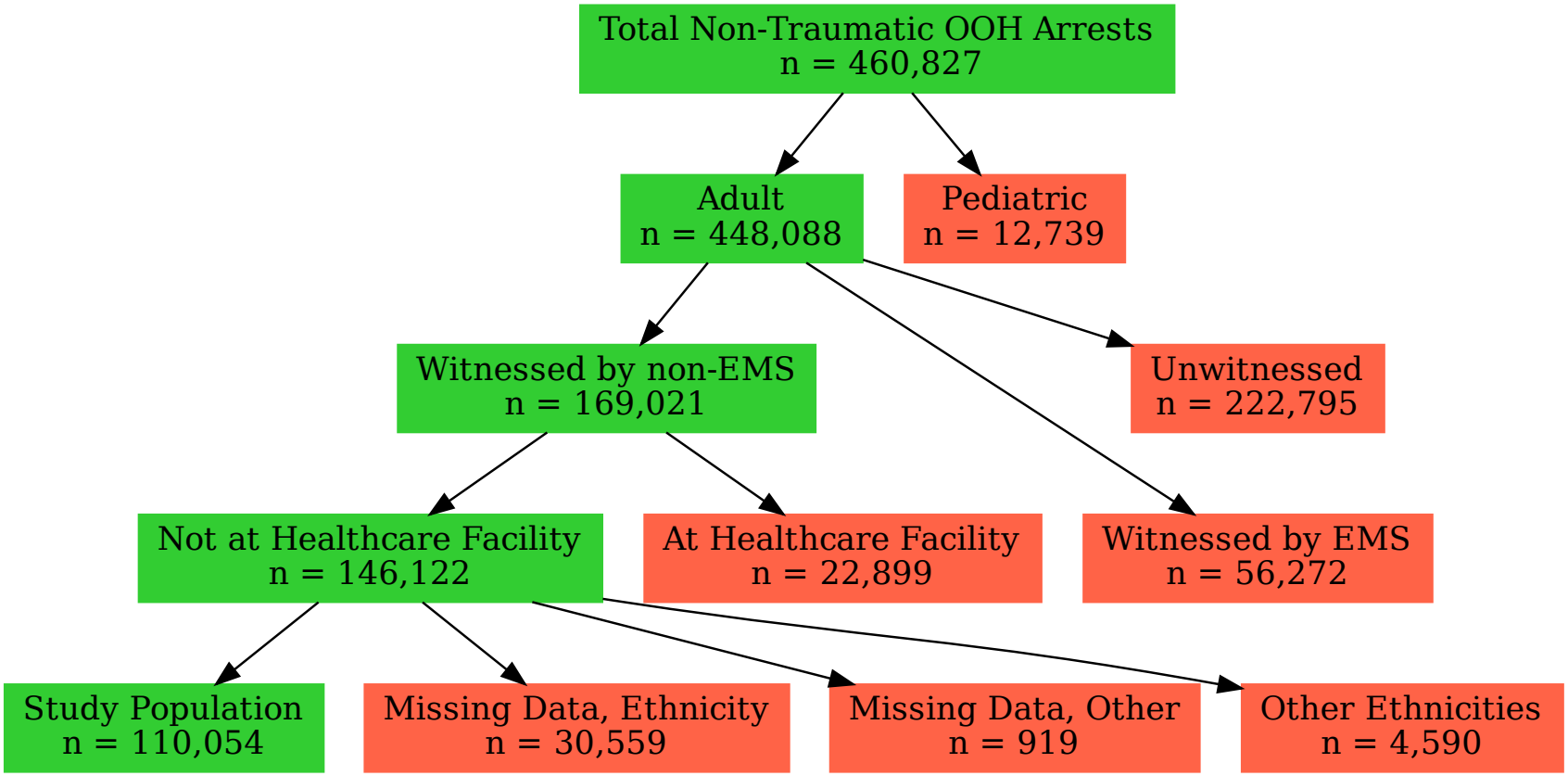
- Problems with this?

Missing Data

- p. 1572 :: "To account for potential bias owing to missing data regarding race or ethnic group, we used inverse probability weighting to generate all model estimates."

- What does this mean?
- Why does missing data matter?

Significant Missing Data



Missing Data, Techniques

- How can data go missing?
  - Missing completely at random
  - Missing at random
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  - Example: depression screening in men

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- How can data go missing?
  - Missing completely at random
  - Missing at random
  - Missing not at random
  - Example: depression screening in men
- How can we deal with missing data?
  - Imputation
    - "filling in" missing values (mean substitution, regression, multiple imputations)
  - Omission
    - withold data with missing values from analysis
  - Analysis
    - use methods unaffected by the missing values

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- authors used *imputation*
- logisitc regression model (think fitting to a line)

MCID: Minimal Clinically Important Difference

"Owing to the large sample size, characteristics of Black or Hispanic persons and White persons at baseline were compared with the use of standardized differences, in which a standardized absolute difference of more than 10 percentage points was considered clinically meaningful."

MCID: Minimal Clinically Important Difference

Table 1. Characteristics of Persons with Witnessed Out-of-Hospital Cardiac Arrest at Baseline.*

Characteristic	All Persons with Cardiac Arrest (N = 110,054)	Black or Hispanic Persons (N = 35,469)	White Persons (N = 74,585)	Standardized Difference†
				percentage points
Year of cardiac arrest — no. (%)				2.9
2013	7,770 (7.1)	2,517 (7.1)	5,253 (7.0)	
2014	10,507 (9.5)	3,378 (9.5)	7,129 (9.6)	
2015	12,038 (10.9)	3,810 (10.7)	8,228 (11.0)	
2016	14,578 (13.2)	4,504 (12.7)	10,074 (13.5)	
2017	18,015 (16.4)	5,871 (16.6)	12,144 (16.3)	
2018	21,137 (19.2)	6,955 (19.6)	14,182 (19.0)	
2019	26,009 (23.6)	8,434 (23.8)	17,575 (23.6)	
Age — yr				24.1
Mean	64.0±15.9	61.4±16.3	65.2±15.5	
Median (IQR)	65.0 (54.0–75.0)	62.0 (51.0–73.0)	66.0 (56.0–76.0)	
Sex — no. (%)				17.8
Female	37,609 (34.2)	14,163 (39.9)	23,446 (31.4)	
Male	72,443 (65.8)	21,305 (60.1)	51,138 (68.6)	
Race or ethnic group — no. (%)‡				NA
Black, non-Hispanic	27,205 (24.7)	27,205 (76.7)	0	
Hispanic or Latino	8,264 (7.5)	8,264 (23.3)	0	
White, non-Hispanic	74,585 (67.8)	0	74,585 (100.0)	

MCID: Minimal Clinically Important Difference

Person initiating CPR — no. (%)				22.8
Layperson of any category	51,852 (47.1)	14,231 (40.1)	37,621 (50.4)	
Unspecified layperson	19,059 (17.3)	5,048 (14.2)	14,011 (18.8)	
Family member	28,280 (25.7)	7,941 (22.4)	20,339 (27.3)	
Medical provider	4,513 (4.1)	1,242 (3.5)	3,271 (4.4)	
First responder	32,294 (29.3)	10,972 (30.9)	21,322 (28.6)	
EMS	25,908 (23.5)	10,266 (28.9)	15,642 (21.0)	
Location of cardiac arrest — no. (%)				4.0
Home or residence	84,296 (76.6)	27,573 (77.7)	56,723 (76.1)	
Public location	25,758 (23.4)	7,896 (22.3)	17,862 (23.9)	
Urbanicity designation — no. (%)§				47.7
Urbanized area	88,490 (80.4)	32,635 (92.0)	55,855 (74.9)	
Urban cluster	7,474 (6.8)	1,209 (3.4)	6,265 (8.4)	
Rural	14,090 (12.8)	1,625 (4.6)	12,465 (16.7)	
Neighborhood median annual household income — no. (%)				65.3
>$80,000	26,504 (24.1)	5,311 (15.0)	21,193 (28.4)	
$40,000 to $80,000	61,075 (55.5)	16,643 (46.9)	44,432 (59.6)	
<$40,000	22,475 (20.4)	13,515 (38.1)	8,960 (12.0)	
Race or ethnic makeup of neighborhood — no. (%)				137.4
More than 50% Black or Hispanic	34,008 (30.9)	23,452 (66.1)	10,556 (14.2)	
Integrated	45,052 (40.9)	10,222 (28.8)	34,830 (46.7)	
More than 80% White	30,994 (28.2)	1,795 (5.1)	29,199 (39.1)	

Multiple Comparisons Problem

- How do we decide if a result is valid / significant?
  - p values! (rejecting the "null hypothesis")
  - example when $\alpha = 0.05$

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  - $\alpha_{total} = 1 - (1 - \alpha_{per.comparison})^m$

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- Family-wise error rate (FWER)
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  - $\alpha_{total} = 1 - (1 - \alpha_{per.comparison})^m$

Number of tests	$\alpha_{per.comparison}$	**FWER**
1	0.05	0.05
5	0.05	0.23
15	0.05	0.54
27	0.05	0.75
100	0.05	0.994

Adjusting for Multiple Testing

- Bonferroni correction
  - $\alpha_{per.comparison} = \frac{\alpha_{total}}{m}$
  - *e.g.* if $m = 5$ and you want $\alpha_{total} = 0.05$, $\alpha_{per.comparison} = \frac{0.05}{5} = 0.01$
- Sidak correction
  - $\alpha_{sidak} = 1 - (1 - \alpha)^{\frac{1}{m}}$
  - *e.g.* if $m = 10$ and $\alpha_{total} = 0.05$,
    $\alpha_{per.comparison} = 1 - (1 - 0.05)^{\frac{1}{10}} = 0.005116$

Adjusting for Multiple Testing

- Bonferroni correction
  - $\alpha_{per.comparison} = \frac{\alpha_{total}}{m}$
  - *e.g.* if $m = 5$ and you want $\alpha_{total} = 0.05$, $\alpha_{per.comparison} = \frac{0.05}{5} = 0.01$
- Sidak correction
  - $\alpha_{sidak} = 1 - (1 - \alpha)^{\frac{1}{m}}$
  - *e.g.* if $m = 10$ and $\alpha_{total} = 0.05$,
    $\alpha_{per.comparison} = 1 - (1 - 0.05)^{\frac{1}{10}} = 0.005116$
- Many others (Tukey's, Holm's, Hocberg's, Dunnett's, harmonic mean procedure, etc.)

How the Paper Dealt with Multiple Testing

p. 1572: "Because **we did not prespecify that there would be correction for multiplicity** when conducting tests, results are reported as point estimates and 95% confidence intervals. The widths of the confidence intervals have not been adjusted for multiplicity, so the intervals should not be used to infer definitive associations."

Takeaway Points

- **Study**
  - Black and Hispanic people get less OOH CPR than Whites
    - no amelioration by location, neighborhood income, or neighborhood ethnic makeup

Takeaway Points

- **Study**
  - Black and Hispanic people get less OOH CPR than Whites
    - no amelioration by location, neighborhood income, or neighborhood ethnic makeup
  - Black and Hispanic people have worse outcomes (survival, neurologic) from OOH arrests than Whites
  - Reasons unclear, but may include sequelae of structural racism, implicit or explicit biases, etc.

Takeaway Points

- **Statistics**
  - Paper methods
    - stratified analysis, logistic regression model
  - Missing data matters!
    - imputed here, but other studies may not mention
  - Think about minimal clinically important difference (MCID)
    - Statistical significance $\neq$ clinical significance
  - Remember issues with multiple testing!
    - p values and confidence intervals both count!
    - Did they account for correction?
    - How should you interpreter p values and confidence intervals?

References

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