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Factors Associated with Hurricane Evacuation: A Statistical Meta-Analysis of Studies, 1999-2018

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Original Research

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Abstract

Objective: Hurricane evacuation is one of the strategies employed by emergency management and other agencies to reduce morbidity and mortality associated with hurricanes. However, factors associated with residents' evacuation decision-making have been inconsistent. In this study, we conducted a statistical meta-analysis to identify factors associated with hurricane evacuation as well as moderators of the evacuation decision.

Methods: A systematic literature search identified 36 studies published between 1999 and 2018. Pooled estimates were calculated using random-effects models, and heterogeneity across studies was checked using both Q and I^2 statistics. Meta-regression methods were used to identify moderators. Publication bias was assessed using both visual (funnel plots) and statistical methods.

Results: Mobile home residence, perception of risk, female sex, and Hispanic ethnicity were statistically associated with hurricane evacuation, while geographic region modified the relationship between Hispanic race and evacuation.

Conclusions: Agencies responsible for preparedness may utilize these findings to identify specific population sub-groups for hurricane evacuation communication and other interventions. Future studies should consider statistical interactions and explore opportunities for research translation to emergency officials.

Introduction

Population growth and development in coastal regions of the highly vulnerable U.S. Atlantic and Gulf Coasts have increased the likelihood of substantial damages from disasters like tropical storms and hurricanes. The number of deaths associated with hurricanes and tropical storms has declined dramatically over the last century due in part to improved forecasting and advanced warning systems that alert residents to evacuate to prevent catastrophic consequences. Therefore, factors that predict hurricane evacuation have been studied extensively.[1-4] Individuals typically make evacuation decisions in the context of actual and perceived risks as well as social and economic constraints. While some predictors of evacuation are consistent across studies, many predictors have had mixed associations with evacuation.

In the first major review of evacuation studies Quarantelli,[5] developed a model of evacuation decision-making that included community context, threat conditions, social processes, patterns of behavior, and community preparedness based on a dozen large scale, random-sample population surveys of communities impacted by floods, tropical storms, hurricanes, tornados, and manmade accidents. In the next review,[2] Baker demonstrated through analysis of a large database constructed from surveys conducted following 12 hurricanes that made landfall in the U.S. between 1961 and 1989 that there were no consistent associations between demographic factors and evacuation. Peacock, Marrow, and Gladwin,[3] used data from Hurricane Andrew, a major Category 5 hurricane that made landfall near Miami, Florida in 1992, and found mixed results when assessing the association between race and evacuation. When demographic and household variables were included in their models and indicators of 'risk' excluded, African-Americans and Hispanics were less likely to evacuate than whites. However, when risk indicators were included, no statistically significant differences in evacuation were observed by race. In addition, household size and the presence of children or elderly in the household were negatively associated with evacuation. The inconsistencies in the association between demographic factors and evacuation were explored by Horney *et al.*,[6] who found that social factors could act as modifiers of the relationship between demographic variables and evacuation.

Mobile home residence has been consistently positively associated with evacuation across multiple studies. Dow and Cutter found that the most significant determinant of hurricane evacuation behavior is a personal perception of risk, which may be the mechanism by which the association between mobile home residents and evacuation operates.[4] Individuals who live in mobile homes likely know their homes are not sturdy enough to withstand hurricane impacts.

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Families that reside in multi-unit buildings were more likely to evacuate than those who lived in single-family homes, who may remain to protect their homes from flooding or looting.[4] In contrast, Horney, *et al.* found no association between individual actual or perceived flood risk and evacuation from Hurricane Isabel in 2003 or Hurricane Irene in 2011.[7]

The assessment of the association between income and evacuation has also yielded mixed results in the observed literature, with some authors reporting a positive relationship,[3-9,21] and others an inverse association.[10-14] The justification for the latter finding has been that residents with higher incomes may perceive their homes to be of higher quality and able to withstand a strong storm or that they may be more likely to remain in their homes to protect valuables. A positive association between income and evacuation may be because wealthier residents may own higher risk coastal properties subject to waves and storm surges and may also evacuate relatively more easily due to their ability to finance expenses associated with evacuation.

Baker's review demonstrated that dissemination of information could predict evacuation.[2] Residents of high-risk coastal areas may be more likely to evacuate when they receive evacuation information from non-media sources like governmental or other public officials or family and friends. They may also be more likely to evacuate when public officials are proactive about issuing evacuation orders. Peacock, Marrow, and Gladwin,[3] made similar observations following Hurricane Andrew. On the other hand, other studies have reported that media sources exerted a significant influence on hurricane evacuation decision.[15] Stein, *et al.* studied the determinants of evacuation following Hurricane Rita, which made landfall in Galveston, Texas, in 2008 and observed that heterogeneity in evacuation was explained by the evacuation designation of their area of residence. Another study in Florida found that residents who live in officially designated evacuation areas responded differently to a set of information cues, incentives, and risk factors than evacuees who live outside of these areas.[16]

It has been hypothesized that racial and ethnic minorities are less likely to evacuate because of differences in social and family networks, risk perceptions, language and communication difficulties, and inadequate access to the resources required for evacuation.[17] However, some prior studies have reported lower evacuation rates in minorities[3]; Some have found lower rates among some minority groups but not others[18]; While others have found no significant differences.[19]

Findings related to the association between length of residence in an area at-risk of hurricanes and evacuations are also mixed. While some authors found a positive association,[2,7] (e.g., longer-term residents were less likely to evacuate), others found a negative or no association with evacuation behavior.[3] Length of residence could impact evacuation decision in various ways. Newer residents could decide to evacuate because of their heightened perceived risk, but they could also choose not to evacuate because of their inexperience with risk in the area. On the other hand, long-term residents could decide to evacuate because of prior experience with hurricane landfalls in the area, or choose not to, because of their perception that the area is safe (e.g., false expectations paradox).[2]

Overall, numerous studies across different fields have been published assessing associations between demographic and other factors and evacuation in response to approaching hurricanes.[3,15,20] Except for a few of these factors, associations with evacuation reported in the literature are highly variable, with studies reporting positive, negative, or null associations.[7,8,10,21] Previous summary studies conducted on this subject were predominantly narrative reviews, which often yielded invalid estimates by not weighting average effect sizes.[1] Hence, this study aims at enumerating factors that predict evacuation to increase the efficiency and effectiveness of evacuation in hurricane emergencies. It may also be reasonable to assert that determinants of hurricane evacuation differ across different disaster events of dissimilar intensity or location. Primary study results may vary by region impacted (e.g., Atlantic or Gulf Coast), the severity of the hurricane (e.g., Category on the Saffir-Simpson scale), evacuation zone,[15] or year of publication.[22] For instance, the year of publication may impact study results if research methods, hurricane severity, or study participants changed over time. In order to identify factors that explain heterogeneity of evacuation decision in hurricane conditions, this study aimed at investigating the moderators of evacuation across studies. The isolation of moderators may enhance disaster planning by emphasizing specific at-risk groups that could be targeted for evacuation communications.[23] Information on sources of heterogeneity may also inform the meta-researcher on the combinability of primary studies, whether summary statistics should be reported in a meta-analysis, and if so, how they should be produced (e.g. by reporting stratified estimates across levels of the moderator).[24]

Research Questions

In order to address gaps in understanding factors that consistently predict hurricane evacuation decision, this paper explores the following 2 research questions:

Research Question 1 (RQ1): What factors significantly predict household hurricane evacuation decision?

Research Question 2 (RQ2): What are the moderators of household hurricane evacuation decision? Do determinants of hurricane evacuation decision differ by geographic region of residence, the severity of hurricane or tropical storm, or publication year of primary studies?

Methods

Search Strategy

We conducted a systematic literature search based on the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (see Figure s1). English language articles published from 1999 to 2018 were identified from Google Scholar (Google Inc, Mountain View, CA), Web of Science (Thomson Reuters, New York, NY), and SCOPUS (Elsevier, Amsterdam, Netherlands) databases. The keywords searched for were "Hurricane" and "Evacuation factors." In order to be included in the study, a paper had to be from a primary study and report either a regression coefficient or adjusted odds ratio on the association between evacuation decision and predictor variables. Articles that reported only correlation coefficients were excluded from the study as they provided crude associations rather than adjusted estimates. References cited in original and review papers were also examined until no further articles were identified. The variables included in the study were mobile home residence, perception of risk, child(ren) in home, marital status, home ownership, peer or neighbor evacuation, social cues, mandatory (official) evacuation orders, previous hurricane exposure, media, education, length of time in residence, race/ethnicity (African-American, white, and Hispanic), and female sex. The total sample size was 33858 (Range: 97 to 3390).

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Table 1. Sources of data included in the statistical meta-analysis

Serial Number	Source of Data	Type of Data Source	Total Number of Studies
1	Horney (2018)	Unpublished manuscript	1
2	Sadri (2017)	Journal article	1
3	Dixon (2017)	Journal article	1
4	Huang (2017)	Journal article	1
5	Sadri (2017)	Journal article	1
6	Brackenridge (2012)	Journal article	1
7	Huang (2012)	Journal article	1
8	Hasan (2010)	Journal article	1
9	Stein (2010)	Journal article	2
10	Solis (2009)	Conference paper	5
11	Smith (2009)	Journal article	6
12	Noltenius (2008)	Doctoral dissertation	1
13	Brezina (2008)	Journal article	1
14	Rosenkoetter (2007)	Journal article	1
15	Elliot (2006)	Journal article	2
16	Van (2005)	Journal article	2
17	Fu (2004)	Doctoral dissertation	2
18	Fu (2004)	Journal article	1
19	Zhang (2004)	Journal article	1
20	Wilmot (2004)	Journal article	1
21	Bateman (2002)	Journal article	1
22	Whitehead (2000)	Journal article	1
23	Riad (1999)	Journal article	1

In compiling the database, a distinction was drawn between an article and a study. An article comprises all the analyses of research subjects, which may be reported in 1 or more studies. An article may, therefore, be composed of 1 or several studies. A total of 36 studies were included for analyses, which were derived from 19 published journal articles, 1 conference paper, 2 doctoral dissertations, and 1 unpublished manuscript (Table 1; Supplemental File 1).

Quantitative and Qualitative Data Extraction

Data were extracted on article title, publication year, article characteristic (1 = Journal article; 2 = Doctoral dissertation; 3 = Conference Paper 4 = Unpublished manuscript), type of effect estimate (1 = Regression coefficient; 2 = Odds ratio), and adjusted effect size (regression coefficient or odds ratio) (see codebook in Supplemental File 2).

Effect Size Conversions

In order to permit the estimation of a common index of effect size for use in the meta-analysis, the adjusted regression coefficients/odds ratios earlier extracted were converted to correlation coefficients using the formula proposed by Field and Gillet.[25] To our knowledge, this is the sole evidence-based approach for the conversion of effect size from odds ratio to correlation coefficient. The method was also adopted by Huang, *et al.* in their conversion of effect size.[1]

In order to account for differential precision of effect sizes associated with sample size variation between studies, the correlation coefficients were subsequently weighted by sample size using Fisher's transformation:

$$Z_r = \sqrt{[Ln(1+r) - (Ln(1-r)]}$$

$$SE_{Zr} = 1/(\sqrt{(n-3)})$$

Where r *– correlation coefficient;* Z_r *– Fishers transformed* r*;* SE_{Zr} *– Std. Error of* Z_r*;* n *– sample size*

The data were then uploaded onto Stata 14 (College Station, Texas), and the pooled Fisher's estimate reconverted to correlation coefficients (Figure s2). Similar to the interpretation employed by Field and Gillet,[25] and Cohen,[26] the strength of the pooled effect size for a variable in this study was described as small if $r \approx 0.1$, medium if $r \approx 0.3$, and large if $r \approx 0.5$.

Statistical Analysis

Due to potential heterogeneity in populations impacted, study designs, hurricane category, and hurricane region, the true effect likely varies between studies in addition to the usual sampling variation within studies. In order to account for both sources of variation, a random-effects meta-analytic model that provided more conservative estimates and larger standard errors was fitted. Heterogeneity across studies was checked using the Q and I^2 statistics. To identify potential causes of heterogeneity, moderator analysis was conducted using meta-regression to test if any of the study characteristics modified the relationship between evacuation and any of the predictor variables. The potential effect modifiers tested were the year of publication, analytic method, the severity of the hurricane, and the hurricane region. Stratum-specific estimates were presented for every effect modifier identified. Finally, publication bias was investigated in 2 ways. First, by observing visual asymmetry in funnel plots (i.e., plots of effect estimates against their estimated precision (reciprocal of the variance) and second, by determining the degree of asymmetry using Egger's unweighted regression asymmetry test. Whenever publication bias was identified, a sensitivity analysis using the Trim-and-Fill Method was conducted to compare adjusted and unadjusted results.

Results

Characteristics of the Articles

The search strategy revealed a total of 19 published journal articles, 1 conference paper, 2 doctoral dissertations, and 1 unpublished manuscript, which reported data from 36 studies conducted between 1999 and 2018 (Table 2).

Research Question 1 (RQ1): What Factors Significantly Predict Household Hurricane Evacuation Decision?

Risk Factor Estimates

The predictors of household hurricane evacuations were mobile home residence (r = 0.31; 95% CI: 0.21, 0.41) (Figure 1, Table 3), perception of risk (r = 0.18; 95% CI: 0.10, 0.26) (Figure 2, Table 3), Hispanic race (r = 0.08; 95% CI: 0.01, 0.14)

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Table 2. Characteristics of published studies on factors that predict hurricane evacuation

First Author	Publication Year	Sample Size (N)	Location	Hurricane Year	Hurricane
Horney	2018	1086	TX	2017	Harvey
Sadri	2017	863	NY, NJ	2012	Sandy
Dixon	2017	586	TX	2008	Ike
Huang	2017	1277	LA, TX	2005	Katrina, Rita
Sadri	2017	1109	NY, NJ	2012	Sandy
Brackenridge	2012	120	TX	2008	Ike
Huang	2012	562	TX	2008	Ike
Hasan	2010	1995	FL, AL, MS, LA	2004	Ivan
*Stein	2010	223	TX (Inside Evac. Zone)	2005	Rita
Stein	2010	318	TX (Outside Evac. Zone)	2005	Rita
*Solis	2009	1355	FL	2005	Katrina, Wilma, Dennis
Solis	2009	360	FL (SE)	2005	Katrina
Solis	2009	506	FL	2005	Wilma
Solis	2009	305	FL (NW)	2005	Dennis
Solis	2009	184	FL (NW)	2005	Katrina
*Smith	2009	1711	FL (Central)	2004	Charley, Frances, Ivan, Jeanne
Smith	2009	1881	FL	2004	Jeanne, Charley, Frances, Ivan
Smith	2009	2739	FL (SE)	2004	Jeanne, Ivan, Charley, Frances
Smith	2009	2105	FL (SW)	2004	Frances, Jeanne, Ivan, Charley
Smith	2009	568	FL (Charlotte)	2004	Jeanne, Frances, Ivan, Charley
Smith	2009	1925	FL (NW)	2004	Jeanne, Frances, Ivan, Charley
Noltenius	2008	287	FL	2005	Wilma
Brezina	2008	680	LA	2005	Katrina
Rosenkoetter	2007	97	GA	2005	Katrina
*Elliot	2006	962	LA	2005	Katrina
Elliot	2006	330	LA (New Orleans)	2005	Katrina
*Van	2005	309	NC (Community Residence)	1999	Floyd
Van	2005	852	NC (School Residence)	1999	Floyd
*Fu	2004	428	LA	1992	Andrew
Fu	2004	1688	SC	1999	Floyd
Zhang	2004	312	TX	1999	Bret
Wilmot	2004	466	LA	1992	Andrew
Fu	2004	3390	LA	1992	Andrew
Bateman	2002	1008	NC	1998	Bonnie
Whitehead	2000	895	NC	1998	Bonnie
Riad	1999	376	FL, SC, NC, GA	1992	Andrew

*Study conducted on multiple sub-populations

(Figure 3, Table 3), and female sex (r = 0.05; 95% CI: 0.00, 0.09) (Figure 4, Table 3). Results also showed heterogeneity between studies for all the pooled effect estimates except length of time in residence ($X^2 = 8.48$, P-value > 0.05; $I^2 = 5.70$). In other words, a majority of the effect sizes were not uniform but varied considerably across studies. Since such variability may be random or systematic, we investigated if study characteristics explained the variability between studies.

Research Question 2 (RQ2): What are the Moderators Of Household Hurricane Evacuation Decision? Do Determinants of Hurricane Evacuation Decision Differ by Geographic Region of Residence, Severity of Hurricane or Tropical Storm, or Publication Year of Primary Studies?

Moderator Analysis

We examined (by meta-regression analysis) the relationship between evacuation and predictor variables according to hurricane severity, hurricane region, and the publication year (Table 4), in order to explore reasons for the observed heterogeneity between studies. Geographic region modified the relationship between Hispanic race and evacuation (Coef. = 0.23; 95% CI: 0.04, 0.42) and publication year modified the relationship between educational level and evacuation (Coef. = 0.06; 95% CI: 0.01, 0.12). Out of the remaining variables (13 of 16), no specific reason for the heterogeneity could be found (Table 4).

When 'Hispanic race' was stratified by the hurricane region (Table s1), we observed that Hispanics in the Atlantic Coast were more likely to evacuate compared to their counterparts in the Gulf Coast (where there was no association between Hispanic race and evacuation).

Publication Bias

Both visual control (Figure s3) and statistical significance (Table s2) identified the presence of publication bias in peer/

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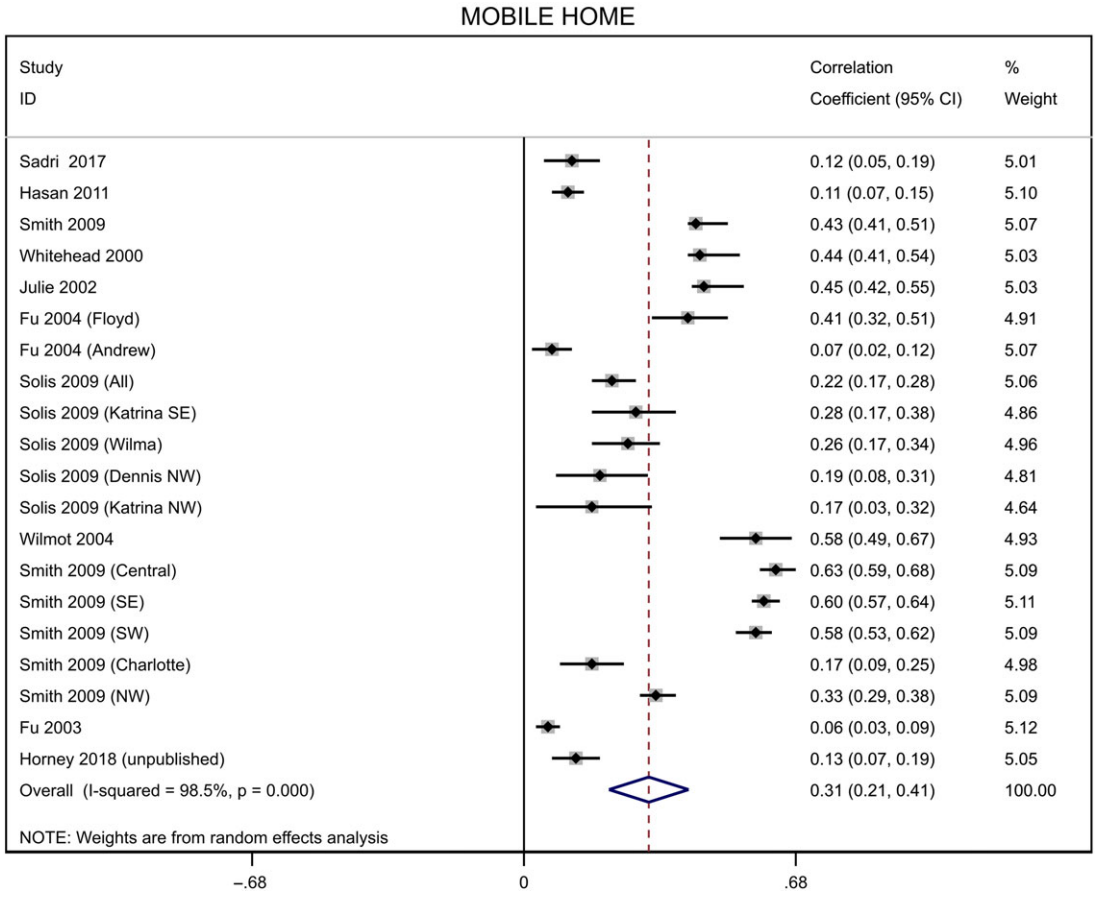


Figure 1. A Forest Plot for the Association of Mobile Home Residence and Hurricane Evacuation.

neighbor evacuation (Bias = −6.50; 95% CI: −12.57, −0.44), length of time in residence (Bias = −2.63; 95% CI: −4.65, −0.60), and media (Bias = −6.83; 95% CI: −13.30, −0.35) (Table s2). Correcting for these biases with Trim and Fill did not change the results (not shown). The authors of this study did not identify publication bias in studies of other predictor variables (Table s2).

Discussion

Across 36 studies, hurricane evacuation was positively correlated with mobile home residence, perception of risk, Hispanic race, and female sex. The effect size for the perception of risk (r = 0.18), Hispanic ethnicity (r = 0.08), and female sex (r = 0.05) are small and thus require additional studies to substantiate the predictability of these variables for evacuation decision-making. The statistical meta-analysis conducted by Huang *et al.* reported that mobile home residence and perception of risk positively predicted hurricane evacuation decision,[1] but demographic variables like sex and Hispanic ethnicity did not significantly predict such decision. Baker,[2] in his systematic review, found that mobile home residence was predictive of hurricane evacuation decisions but not sex (the author did not study the perception of risk and Hispanic ethnicity). The inconsistency between our findings and Huang's and Baker's,[1,2] may be attributable to the differences in statistical methods employed in the studies. Unlike the previous 2 studies, which estimated average effect size, our study fitted a random-effects meta-analysis and estimated a pooled effect size by inverse variance weighting.

The positive correlation between mobile home residence and evacuation may be explained by the increased perception of the structural vulnerability of residents, which contributes to the decision to evacuate.[1,2] Evacuation orders are essential because residents perceive officials as having a high knowledge of hazards as well as the duty to warn and protect households by disseminating accurate information on impending risks.[1] Since perception of risk estimates the self-rated threat of a hurricane to individuals, their families, and properties, it is reasonable to anticipate a positive relationship between this variable and the decision to evacuate.[27-29] Finally, the positive correlation between female sex and evacuation may be due to the women's actual or perceived social vulnerabilities and caregiving roles in households, which heighten risk perception.[19,30] Fothergill, *et al.*,[17] also asserted that women have a higher likelihood of perceiving disaster as severe and risky. The meta-analytic study conducted by Huang, *et al.* also reported a positive correlation between female sex and evacuation (r = 0.08; 95% CI: 0.02, 0.14) for actual hurricane studies.[1]

Moderator Analysis

Highly vulnerable regions of the U.S., such as the Atlantic and Gulf Coasts have a high and growing proportion of Hispanic residents. As the Hispanic population in the U.S. increases, more research is needed on the relationship between Hispanic ethnicity and evacuation behavior.[31-33] Hispanics in the Atlantic and Gulf Coasts differ in terms of reported health and well-being, education, English language comprehension, size of a social network,

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Table 3. Pooled (summary) and heterogeneity estimates of factors that predict hurricane evacuation

Predictive Factors	No of studies (K)	Summary Estimate		Heterogeneity Estimates	
		Pooled *r*	95% CI	X^2	I^2
Mobile Home	20	*0.31	0.21, 0.41	*1236.33	*98.50
Perception of Risk	9	*0.18	0.10, 0.26	*86.21	*90.70
Child(ren) in Home	14	0.07	−0.01, 0.14	*128.21	*89.90
Married	8	−0.02	−0.14, 0.09	*136.54	*94.90
Own Home	18	−0.03	−0.12, 0.06	*596.12	*97.10
Peer/Neighbor Evacuation	12	−0.07	−0.17, 0.03	*224.45	*95.10
Social Cues	6	0.04	−0.06, 0.14	*67.11	*92.50
Mandatory/Official Evacuation Order	13	0.18	−0.02, 0.37	*1568.56	*99.20
Previous Hurricane Exposure	10	0.02	−0.01, 0.05	*17.36	*48.10
Media	5	−0.10	−0.25, 0.05	*46.83	*91.50
Education (at least High School)	15	0.01	−0.02, 0.03	*29.49	52.50*
Length of Time in Residence	9	−0.01	−0.03, 0.01	8.48	5.70
Black	12	0.06	−0.14, 0.26	*1465.92	*99.20
Hispanic	10	*0.08	0.01, 0.14	*109.63	*91.80
White	10	0.05	−0.05, 0.15	*127.33	*92.90
Female	17	*0.05	0.00, 0.09	*116.05	*86.20

*P-value < 0.05

risk perception, and access to economic resources to finance evacuation.[17,34,35] Hispanics are also a heterogeneous group of individuals from at least 25 countries in Central and South America and the Caribbean. The Hispanic population along the U.S. Atlantic coast is comprised predominantly of Puerto Ricans, while the population of Hispanics living along the U.S Gulf-coast is primarily from Mexico. Factors such as country of origin and nativity status may have implications for Hispanic residents faced with making a decision to evacuate from an oncoming hurricane.[36]

This study has several strengths. First, it has improved on a previous meta-analysis conducted by Huang, *et al.*,[1] by including more recent articles, analyzing only actual (rather than hypothetical) hurricane studies, and estimating pooled effect sizes using random-effects models. Second, the study employed moderator analyses, including meta-regression, to explore the possible sources of heterogeneity across studies, allowing for the isolation of moderators within which predictor variables were stratified. Third, publication bias was assessed using visual (funnel plots) and statistical (Egger's regression) methods. Sensitivity analysis was also conducted to investigate any difference between biased and adjusted results. Given that publication bias was found among 3 of the 16 variables studied (peer/neighbor evacuation, length of time in residence, and reliance on media), published studies were more likely to report statistically significant findings for these variables compared to the grey literature. However, sensitivity analysis results showed that similar effect sizes would be obtained even in the absence of publication bias. The lack of publication bias among 13 of the 16 variables studied might be attributed to the systematic literature search conducted and the inclusion of both published and grey literature.

Although we have made a comprehensive summary of the factors that predict hurricane evacuation in the literature, there are still limitations that merit discussion. First, pooled estimates were presented in the form of correlation coefficients rather than odds ratios. Since the latter adjust for potential confounding factors, their results are preferred. However, we could not present summary odds ratios because most of the primary studies did not provide sufficient sample size information to calculate pooled odds ratio estimates. Second, some stratified estimates (on moderators) were associated with few studies ($K < 6$) across sub-sets of the predictor variables. Although a meta-analysis could be conducted on a minimum of 2 published studies, Sanchez-Meca and Marin-Martinez's Monte Carlo simulation recommended that only tentative conclusions be drawn on meta-analysis for which the number of studies is less than 6.[37] This may have accounted for statistically non-significant findings in some strata (e.g., Hispanics in the Gulf-Coast). Third, this study analyzed only hurricane evacuation factors but neglected the possibility that other disasters may lead to similar decision-making processes (such as tornado warnings that were not considered). Fourth, as this study is a meta-analysis, predictors of evacuation decision were explored if they had been sufficiently reported in past primary studies. Thus, our study is not exhaustive of all the predictors of hurricane evacuation decision. For example, we did not assess the impact of potential predictors like fear of traffic congestion and lack of transportation as they were either under-reported in primary studies or did not provide sufficient statistical information to permit estimation of effect size. For similar reasons, the evacuation behavior of other racial/ethnic minorities like Asian-Americans and Pacific Islanders was not assessed in this study. To overcome potential meta-analytic limitations, future primary studies should explore additional predictors of hurricane evacuation decision and report sufficient data to permit meta-analytic effect size estimation. Finally, this study identified heterogeneity in nearly all predictor variables (except length of residence), but only explained the possible causes of this phenomenon in 12.5% (2 of 16) of the randomly defined effect sizes. As isolation of effect modifiers may enable the targeting of specific at-risk groups during hazard planning, future primary studies should explore potential heterogeneity of factors that moderate evacuation decision.

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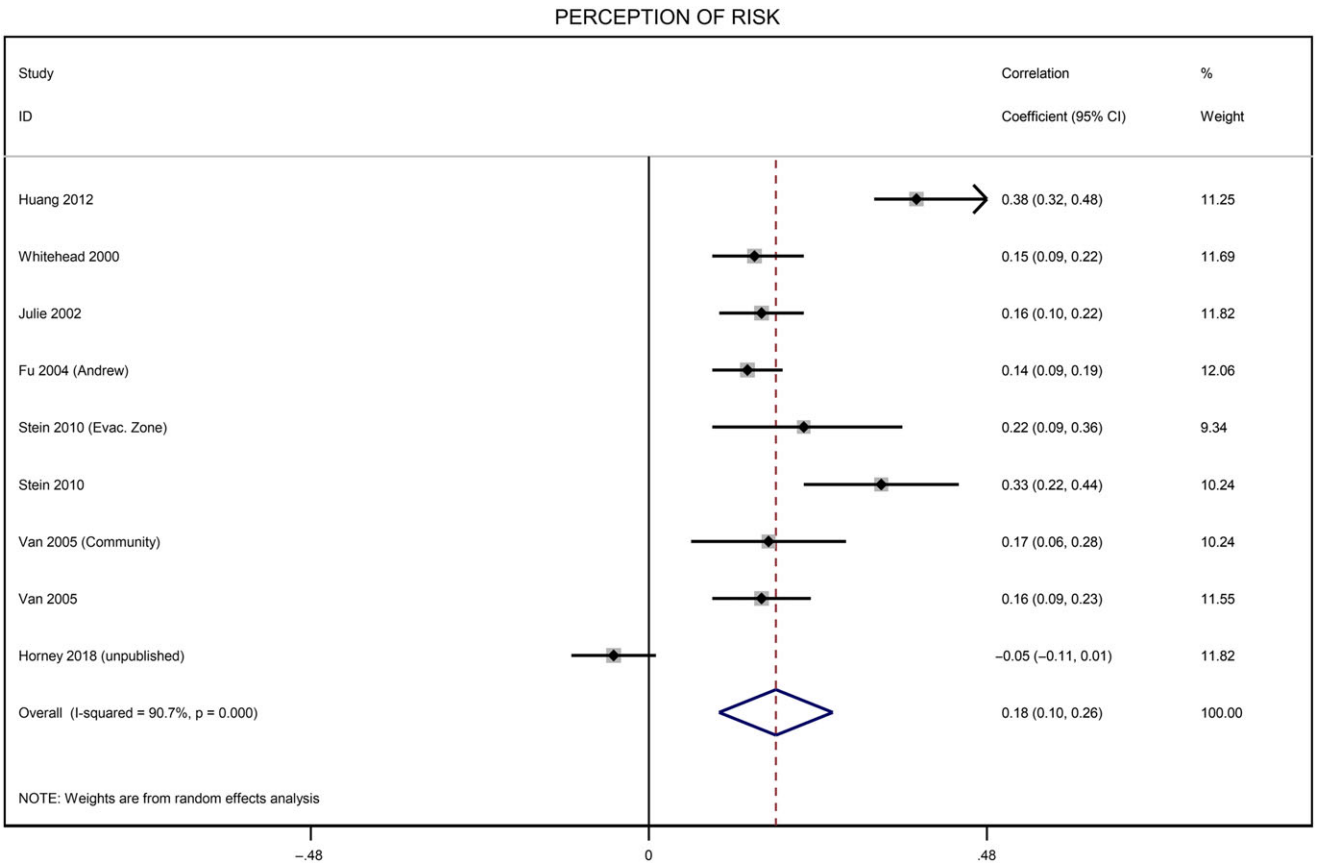


Figure 2. A Forest Plot for the Association of Risk Perception and Hurricane Evacuation.

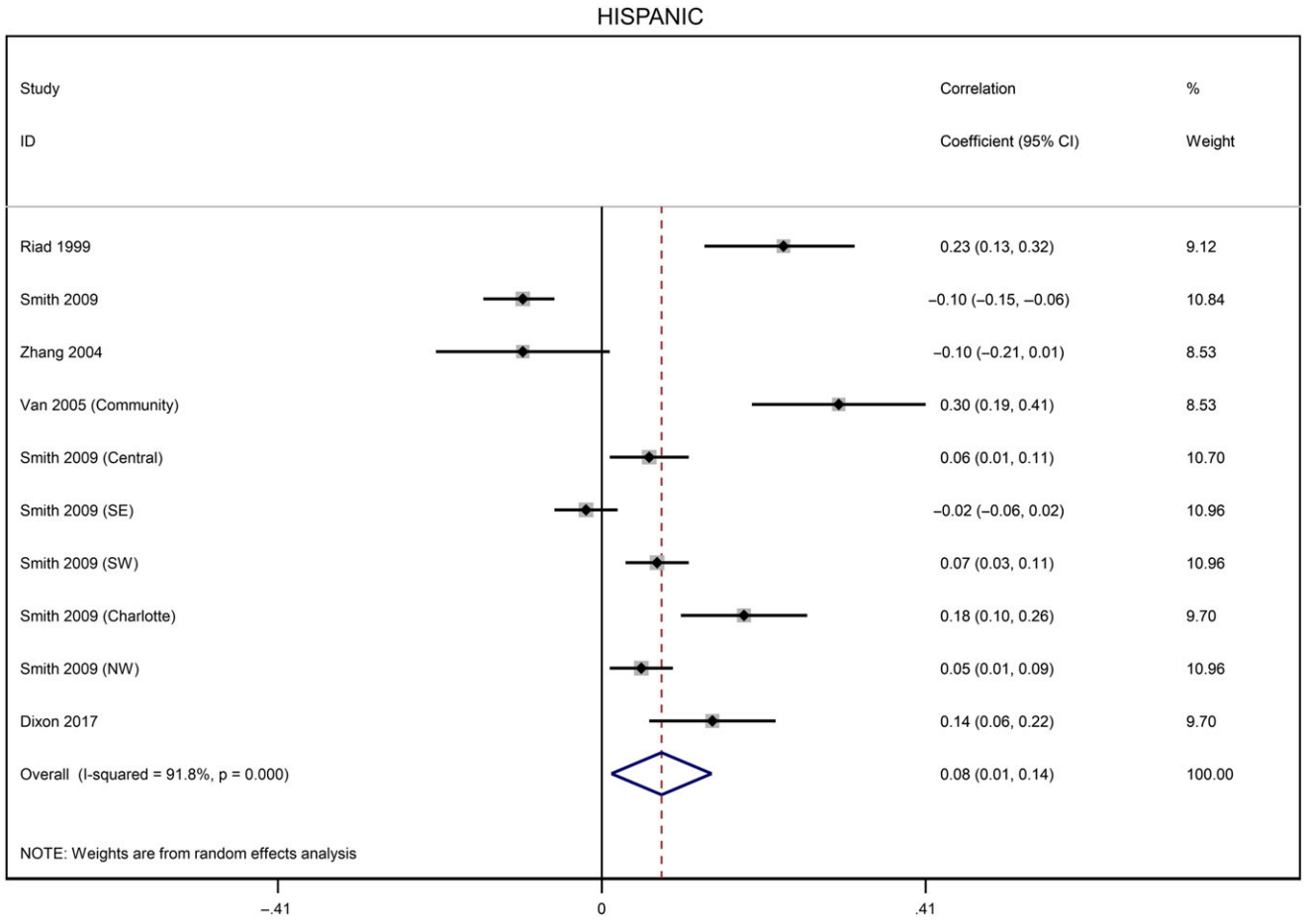


Figure 3. A Forest Plot for the Association of Hispanic Ethnicity and Hurricane Evacuation.

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Table 4. Meta-regression analysis of potential moderators on predictive factors

	Hurricane Category		Hurricane Region		Publication Year	
Predictive Factors	Coef.	95% CI	Coef.	95% CI	Coef.	95% CI
Mobile Home	0.04	−0.09, 0.16	−0.05	−0.28, 0.18	−0.23	−0.46, 0.00
Perception of Risk	0.06	−0.09, 0.21	−0.06	−0.27, 0.15	0.06	−0.15, 0.27
Child(ren) in Home	0.08	−0.09, 0.24	−0.07	−0.32, 0.18	−0.04	−0.28, 0.19
Married	−0.06	−0.22, 0.11	0.07	−0.23,0.36	0.10	−0.18, 0.38
Own Home	0.09	−0.14, 0.31	−0.15	−0.46,0.16	−0.03	−0.30, 0.24
Peer/Neighbor Evacuation	−0.06	−0.30, 0.17	−0.15	−0.55,0.25	−0.09	−0.39, 0.20
Social Cues	0.06	−0.15, 0.27	−0.08	−0.43,0.27	−0.10	−0.58, 0.38
Mandatory/Official Evacuation Order	0.03	−0.26, 0.33	−0.26	−0.76, 0.23	−0.11	−0.59, 0.37
Previous Hurricane Exposure	−0.06	−0.16, 0.03	−0.06	−0.21, 0.08	−0.02	−0.10, 0.05
Media Influence	−0.17	−0.35, 0.00	0.08	−0.51, 0.66	0.15	−0.58, 0.88
Education (at least High School)	−0.01	−0.05, 0.03	0.00	−0.07, 0.06	*0.06	0.01, 0.12
Hispanic	−0.05	−0.27, 0.17	0.23*	0.04, 0.42	0.07	−0.27, 0.40
White	0.11	−0.06, 0.27	−0.02	−0.34, 0.30	−0.17	−0.43, 0.09
Female	0.01	−0.07, 0.09	0.07	−0.07, 0.21	−0.08	−0.20, 0.04

*P-value < 0.05

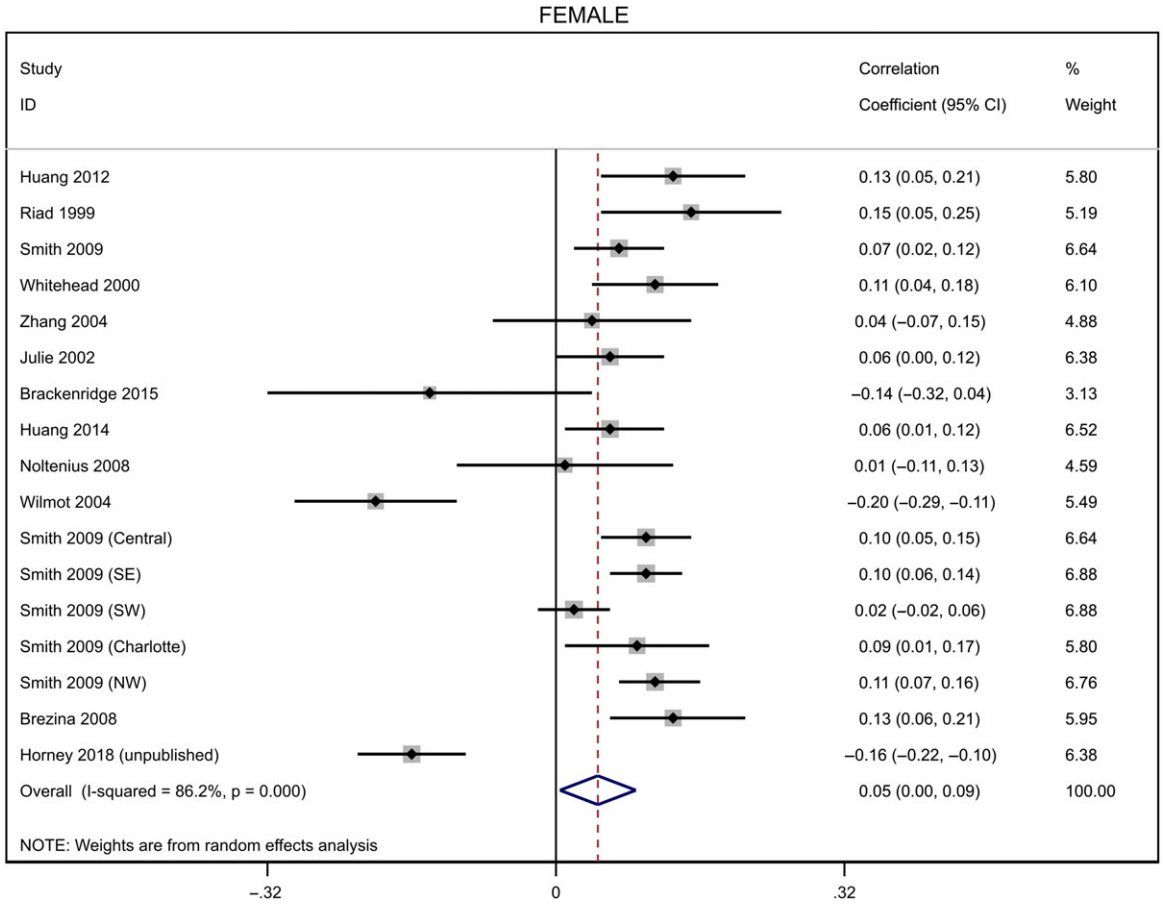


Figure 4. A Forest Plot for the Association of Female Sex and Hurricane Evacuation.

Conclusion

The identification and research translation of factors associated with hurricane evacuation decision enables emergency managers and other officials to develop interventions targeted to specific population sub-groups. However, factors associated with hurricane evacuation decision have been inconsistent. Through a statistical meta-analysis, factors that predict evacuation across studies, as well as moderators of these associations, were identified. Mobile home residence, perception of risk, female sex, and Hispanic ethnicity were associated with hurricane evacuation,

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while geographic region modified the relationship between Hispanic ethnicity and hurricane evacuation. Future studies should explore statistical interactions to identify additional moderators of hurricane evacuation decisions and work with practitioners to ensure that data are applied to the development and implementation of interventions.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/dmp.2021.24

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References

1. **Huang S-K, Lindell MK, Prater CS.** Who leaves and who stays? A review and statistical meta-analysis of hurricane evacuation studies. *Environment and Behavior.* 2016;48(8):991–1029.
2. **Baker EJ.** Hurricane evacuation behavior. *IJMED.*1991;9(2):287–310.
3. **Peacock WG, Morrow BH, Gladwin H.** *Hurricane Andrew: Ethnicity, gender and the sociology of disasters.* London, New York: Routledge; 1997: 52–73.
4. **Dow K, Cutter SL.** "Crying Wolf: Repeat responses to hurricane evacuation orders." *Coastal Management.* 1998;26:237–252.
5. **Quarantelli EL.** *Evacuation Behavior and Problems: Findings and Implications from the Research Literature.* Ohio State Univ Columbus Disaster Research Center; 1980.
6. **Horney JA, MacDonald PD, Willigen M, Kaufman JS.** The importance of effect measure modification when using demographic variables to predict evacuation. *RHCPP.* 2012;3(1):1–19.
7. **Horney JA, Macdonald PD, Van Willigen M, Berke PR, Kaufman JS.** Individual actual or perceived property flood risk: Did it predict evacuation from Hurricane Isabel in North Carolina, 2003? *Risk Anal.* 2010;30(3): 501–511.
8. **Huang SK, Lindell MK, Prater CS, Wu HC, Siebeneck LK.** Household evacuation decision making in response to Hurricane Ike. *Nat Hazards Review.* 2012;13(4):283–296.
9. **Noltenius MS.** *Capturing pre-evacuation trips and associative delays: A case study of the evacuation of Key West Florida for Hurricane Wilma. Perception, social influence, and access to resources* [dissertation]. University of Tennessee, Knoxville; 2008.
10. **Ng M, Diaz R, Behr J.** Inter-and intra-regional evacuation behavior during Hurricane Irene. *Travel Behav Soc.* 2016;3:21–28.
11. **Elliott JR, Pais J.** Race, class, and Hurricane Katrina: Social differences in human responses to disaster. *Soc Sci Res.* 2006;35(2):295–321.
12. **Willigen VM, Edwards B, Lormand S, Wilson K.** Comparative assessment of impacts and recovery from Hurricane Floyd among student and community households. *Nat Hazards Review.* 2005;6(4):180–190.
13. **Whitehead JC, Edwards B, Willigen VM, Maiolo JR, Wilson K, Smith KT.** Heading for higher ground: Factors affecting real and hypothetical hurricane evacuation behavior. *Global Environmental Change Part B: Environ Hazards.* 2000;2(4):133–142.
14. **Smith SK, McCarty C.** Fleeing the storm(s): An examination of evacuation behavior during Florida's 2004 hurricane season. *Demography.* 2009;46(1): 127–145.
15. **Stein RM, Dueñas-Osorio L, Subramanian D.** Who evacuates when hurricanes approach? The role of risk, information, and location. *Soc Sci Q.* 2010;91(3):816–834.
16. **Peacock WG, Brody SD, Highfield W.** Hurricane risk perceptions among Florida's single-family homeowners. *Landsc Urban Plan.* 2004;83:120–135.
17. **Fothergill A, Maestas EGM, Darlington JD.** Race, ethnicity and disasters in the United States: A review of the literature. *Disasters.* 1999;23(2): 156–173.
18. **Riad JK, Norris FH, Ruback RB.** Predicting evacuation in two major disasters: Risk perception, social influence, and access to resources. *J Appl Soc Psychol.* 1999;29(5): 918–934.
19. **Bateman JM, Edwards B.** Gender and evacuation: A closer look at why women are more likely to evacuate for hurricanes. *Nat Hazards Review.* 2002;3(3):107–117.
20. **DeYoung SE, Wachtendorf T, Farmer AK, Penta SC.** NOAA radios and neighborhood networks: Demographic factors for channel preference for hurricane evacuation information. *J Contingencies Crisis Manag.* 2016; 24(4):275–285.
21. **van Houwelingen HC, Arends LR, Stijnen T.** Advanced methods in meta-analysis: Multivariate approach and meta-regression. *Stat Med.* 2002; 21(4):589–624.
22. **Greenland S.** Interactions in epidemiology: Relevance, identification, and estimation. *Epidemiology.* 2009;20(1):14–17.
23. **Blair A, Burg J, Foran J, *et al.*** Guidelines for application of meta-analysis in environmental epidemiology. ISLI Risk Science Institute. *Regul Toxicol Pharmacol.* 1995;22(2):189–197.
24. **Field AP, Gillett R.** How to do a meta-analysis. *Br J Math Stat Psychol.* 2010;63(Pt 3):665–694.
25. **Cohen J.** A power primer. *Psychol Bull.* 1992;112(1):155–159.
26. **Mileti DS, Peek L.** The social psychology of public response to warnings of a nuclear power plant accident. *J Hazard Mater.* 2000;75(2-3):181–194.
27. **Mileti DS, Sorensen JH.** *Communication of Emergency public Warnings: A Social Science Perspective and State-of-the-art Assessment* (No. ORNL-6609). Oak Ridge National Lab., TN (USA); 1990.
28. **Sorensen JH, Sorensen BV.** Community processes: warning and evacuation. In: *Handbook of Disaster Research.* New York, NY: Springer, NY; 2007:183–199.
29. **Davidson DJ, Freudenburg WR.** Gender and Environmental Risk Concerns: A Review and Analysis of Available Research. *Environment and Behavior.* 1996;28(3):302–339.
30. **U.S. Census Bureau.** *The nation's population is becoming more diverse*: 2017. https://www.census.gov/newsroom/press-releases/2017/cb17-100.html. Accessed February 5, 2019.
31. **Passel J, Cohn D.** U.S. Population Projections 2005–2050. Washington, DC: Pew Research Center's Pew Hispanic Center; 2010.
32. **U.S. Census Bureau.** Statistical abstract of the United States: 2009. https://www.census.gov/library/publications/2009/compendia/statab/129ed.html. Accessed February 5, 2019.
33. **Bustamante AV, Fang H, Rizzo JA, Ortega AN.** Heterogeneity in health insurance coverage among US Latino adults. *J Gen Intern Med.* 2009;24 Suppl 3(Suppl 3):561–566.
34. **Zsembik BA, Fennell D.** Ethnic variation in health and the determinants of health among Latinos. *Soc Sci Med.* 2005;61(1):53–63.
35. **Borrell LN, Crawford ND.** All-cause mortality among Hispanics in the United States: Exploring heterogeneity by nativity status, country of origin, and race in the National Health Interview Survey-linked Mortality Files. *Ann Epidemiol.* 2009;19(5):336–343.
36. **Sánchez-Meca J, Marín-Martínez F.** Homogeneity tests in meta-analysis: A Monte Carlo Comparison of Statistical Power and Type I Error. *Quality and Quantity.* 1997;31(4):385–399.