ORIGINAL ARTICLE

Factors Associated with Healthcare Worker Acceptance of Vaccination: A Systematic Review and Meta-analysis

Marija Vasilevska, BA;[1] Jennifer Ku, MSc;[2] David N. Fisman, MD, MPH, FRCPC[1]

BACKGROUND AND OBJECTIVE. Healthcare workers experience occupational risk of infection and may transmit infections to patients. Vaccination provides an efficient means of protecting workers and patients, but uptake may be low. We sought to identify factors influencing vaccine acceptance by healthcare workers in order to obtain insights leading to more effective vaccination programs in this population.

DESIGN. Systematic review and meta-analysis.

METHODS. We searched Medline, Embase, and CINAHL databases to identify studies published up to May 2012. Factors influencing vaccination acceptance were devised a priori. Random-effects meta-analysis was performed to generate summary estimates of effect. Heterogeneity and publication bias were explored using statistical tools.

RESULTS. Thirty-seven studies evaluating a variety of vaccines (against influenza, pertussis, smallpox, anthrax, and hepatitis B) were included. Homogeneous effects on vaccine acceptance were identified with desire for self-protection (odds ratio [OR], 3.42 [95% confidence interval (CI), 2.42–4.82]) and desire to protect family and friends (OR, 3.28 [95% CI, 1.10–9.75]). Concern that vaccine transmits the illness it was meant to prevent decreased acceptance (OR, 0.42 [95% CI, 0.30–0.58]). Differences in physician and nurse acceptance of immunization were seen between Asian and non-Asian studies.

CONCLUSIONS. Consideration of self-protection (rather than absolute disease risk or protection of patients) appears the strongest and most consistent driver of healthcare workers' decisions to accept vaccination, though other factors may also be impactful, and reasons for between-study divergence in effects is an important area for future research. This finding has important implications for the design of programs to enhance healthcare worker vaccine uptake.

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Infectious diseases pose an important threat to both patients and workers in the healthcare setting. Transmission of influenza, pertussis, respiratory syncitial virus, *Mycoplasma pneumonia*,[1-4] and other pathogens by infected healthcare workers may have disastrous consequences for patients already compromised by the health condition leading to hospitalization. Transmission of pathogens like those above as well as uncommon pathogens, such as SARS coronavirus, creates risk for healthcare workers.[5]

Influenza may be the most commonly transmitted, potentially virulent respiratory pathogen in the healthcare setting.[6] Influenza vaccination of healthcare workers is inexpensive and safe and reduces transmission to both workers and patients.[7,8] Nonetheless, the uptake of influenza vaccination by healthcare workers is disappointing.[2] Attempts to mandate vaccination for these workers have been met with considerable resistance from professional organizations and unions.[9] More recently, it has been suggested that healthcare workers whose immunity to pertussis has waned may transmit pertussis to patients, particularly in the pediatric setting.[3] The US Advisory Committee on Immunization Practices advocates receipt of a booster dose of diphtheria-tetanus-acellular pertussis vaccine by healthcare workers in order to prevent transmission to patients; however, the historical challenges in attaining high rates of influenza vaccination in healthcare workers suggest that uptake of pertussis boosting by this group may be limited.

While the reasons for healthcare worker refusal of vaccination are likely to be numerous, complex, and interrelated, the ability to increase voluntary vaccination uptake requires that they be well understood. Recent systematic reviews and a meta-analysis study have identified important predictors of acceptance of influenza vaccination in healthcare workers,[10-12] but to our knowledge there has been no attempt to generate a systematic review of characteristics and beliefs that are nondisease specific, more broadly predictive of vaccine acceptance by individual healthcare workers. The broader approach to reasons for accepting or refusing vac-

Affiliations: 1. Dalla Lana School of Public Health, University of Toronto, Toronto, Ontario, Canada; 2. School of Kinesiology and Health Studies, Queen's University, Kingston, Ontario, Canada.

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cination by healthcare workers could potentially identify predictive factors that might have been overlooked when focusing on specific diseases/vaccines or confirm already identified predictors by previous studies. Our objectives were to conduct such a review, to quantify the relative strength of factors favoring vaccine acceptance, and to identify evidence and sources of between-study heterogeneity in the relative strength of factors predictive of vaccine acceptance.

METHODS

Search Strategy

We performed a systematic search of the available medical literature, using the Ovid interface to search Medline, Embase, and CINAHL databases to identify relevant studies published up to May 2012. Search terms included "vaccination" or "immunization" and "health personnel" or "health personnel attitude" or "hospital personnel" or "medical personnel" or "medical staff, hospital" or "nurse" or "physician" or "guideline adherence." Additional studies were identified from the reference lists of retrieved articles and by using the Google Scholar search engine (http://scholar.google.ca). The titles and abstracts of all identified citations were reviewed electronically by 2 reviewers (M.V. and J.K.). Studies that could not be excluded on the basis of this initial review were retrieved and reviewed in full. Any disagreements regarding study selection and data extraction were resolved through discussion.

Inclusion and Exclusion Criteria and Study Quality Assessment

We included original research studies that evaluated (1) vaccine uptake by healthcare workers employed in inpatient or outpatient medical settings and/or long-term care centers and either (2) provided a quantitative description of characteristics of individuals who received or intended to receive vaccination—as well as those who did not (or did not intend to) receive vaccination—sufficient for calculation of odds ratios (ORs) or (3) provided ORs or relative risks for factors associated with vaccination, with confidence intervals or other information sufficient for calculation of standard errors.

We excluded studies that evaluated only aggregate changes in vaccine uptake after introduction of measures to enhance uptake, studies restricted to first responders other than emergency medical personnel (eg, police or firefighters), studies restricted to other occupational groups (eg, military personnel), and studies in which the majority of subjects were children or minors. No language restrictions were placed on the search. Because our interest was in identifying factors associated with voluntary acceptance of vaccination, we did not include studies that described coercion as a means of increasing vaccine uptake.[13-15]

We assessed the methodological quality of the studies by using the Downs and Black grading approach,[16] according to the following quality criteria: (1) clearly stated aim, (2) clearly defined study population, (3) study sample representative of

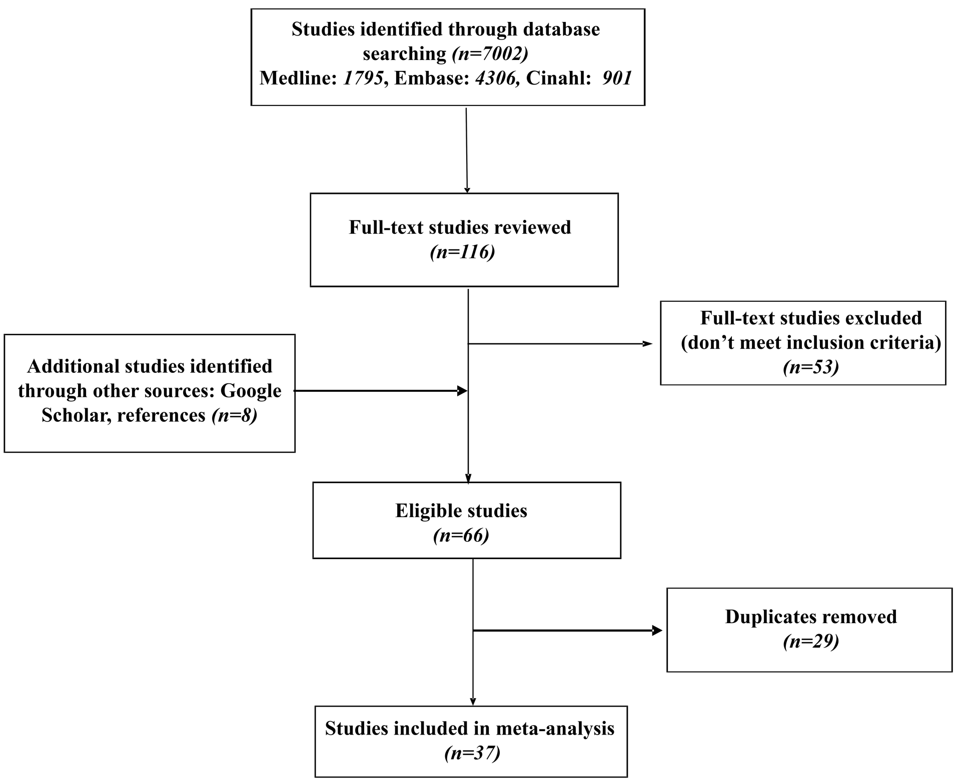

FIGURE 1. Flow diagram representing the process of identifying and including studies in the meta-analysis.

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TABLE 1. Study Characteristics

Study and year published	Country	Year(s) studied	Population studied	Vaccine	n	Response rate, %	Vaccine coverage, %	Quality grading
Al-Tawfiq et al,[26] 2009	Saudi Arabia[a]	2007	HCWs at infection control symposium	Seasonal influenza	450	54	51	3
Arda et al,[28] 2011	Turkey	2009	HCWs at large university hospital	Pandemic influenza A (H1N1)	884	91	18	6
Barrière et al,[29] 2010	France	2009–2010	All HCWs at 2 cancer centers	Pandemic influenza A (H1N1)	1,933	26	31	4
Bautista et al,[30] 2006	Spain	2003	University hospital HCWs	Seasonal influenza	485	89	10	6
Beguin et al,[23] 1998	Belgium	1995–1996	University hospital HCWs	Seasonal influenza	4,109	37	32	4
Briggs et al,[31] 1994	UK	1990	Health district higher-risk HCWs	Hepatitis B	462	65	67	1
Chor et al,[25] 2011	HK, SG, UK	2010	Acute and chronic care hospital HCWs	Pandemic influenza A (H1N1)	6,318	33	30[b]	4
Christini et al,[32] 2007	US	2005	HCWs at 2 teaching hospitals	Seasonal influenza	2,467	42	52	3
Doebbeling et al,[33] 1997	US	1991–1992	University medical center HCWs	Seasonal influenza	7,320	...	32	5
Everett et al,[34] 2004	US	2002	HCWs at 5 academic pediatric EDs	Smallpox	811	52	72	3
Fowler et al,[35] 2006	US	2002–2004	Lab staff at 44 LRN laboratories	Anthrax	430	94	66	5
Goins et al,[36] 2007	US	2006	Tertiary care medical center HCWs	Pertussis	14,893	12	13	4
Heimberger et al,[37] 1995	US	1989–1990	Psychiatric facility employees	Seasonal influenza	1,293	71	19	2
LaVela et al,[38] 2004	US	2002	Spinal cord injuries/disorders HCWs	Seasonal influenza	1,556	73	51	5
Lee et al,[39] 1997	US	1994	Paramedics and EMTs at urban fire department	Hepatitis B	1,250	24	78	3
Lester et al,[40] 2003	Canada	2000	University of Toronto residents	Seasonal influenza	1,195	58	51	3
Manuel et al,[41] 2002	Canada	1999	All HCWs at 2 LTC facilities	Seasonal influenza	401	58	39	3
Martinello et al,[42] 2003	USA	2000–2001	HCWs at large urban teaching hospital	Seasonal influenza	215	99	73	4
Nichol et al,[43] 1997	USA	1994	Medical center physicians and nurses	Seasonal influenza	1,031	38	61	4
Norton et al,[44] 2008	Canada	2008	Nurses at tertiary care urban hospital	Seasonal influenza	1,230	48	76	4
Nowalk et al,[45] 2008	US	2006	HCWs at 6 UPMC hospitals	Seasonal influenza	1,195	61	77	4
O'Reilly et al,[46] 2005	UK	2001	Elderly unit nurses at 3 hospitals	Seasonal influenza	400	51	37	3
Panhotra et al,[47] 2005	US	2003	HCWs at large tertiary care center	Hepatitis B	1,302	100	72	4
Pareek et al,[22] 2009	UK	2007	National Health Service trust HCWs	Influenza A (H5N1)	525	99	58	5
Piccirillo et al,[48] 2006	US	2004	Urban community hospital ED staff	Seasonal influenza	230	87	50	5
Qureshi et al,[24] 2004	UK	2000–2001	National Health Service trust HCWs	Seasonal influenza	1,040	53	28	3
Rubin et al,[49] 2011	UK	2009	National Health Service HCWs	Seasonal influenza and pandemic influenza A (H1N1)	3,129	9	39, 56	4
Saluja et al,[50] 2005	Canada	1999–2000	ED personnel at 4 teaching hospitals	Seasonal influenza	426	80	37	5
Seale et al,[51] 2011	China	2009–2010	HCWs at 19 hospitals	Seasonal influenza and pandemic influenza A (H1N1)	1,657	...	13, 25	3
Song et al,[52] 2006	Korea	2000–2004	HCWs	Seasonal influenza	2,227	25	64[c]	2
Steiner et al,[53] 2002	US	1999	Tertiary care hospital HCWs	Seasonal influenza	2,717	84	78	4
Takayanagi et al,[54] 2007	Brazil	2004	Tertiary teaching hospital HCWs	Seasonal influenza	376	69	34	3
Topuridze et al,[55] 2010	R of Georgia	2007	Physicians/nurses at 2 large hospitals	Hepatitis B	325	91	12	5
Trivalle et al,[56] 2006	France	2004–2005	Geriatric hospital HCWs	Seasonal influenza	412	95	21	6
Walker et al,[57] 2006	US	2002	All HCWs from 1989–2002 surveys	Seasonal influenza	2,089	...	38	5
Weingarten et al,[58] 1989	US	1987	Teaching hospital physicians and nurses	Seasonal influenza	463	41	5	2
Yanturali et al,[59] 2005	Turkey	2003	University-affiliated ED physicians	Smallpox	138	91	22	3

NOTE. ED, emergency department; EMT, emergency medical technicians; HCW, healthcare worker; HK, Hong Kong; LRN, Laboratory Response Network; LTC, long-term care; R of Georgia, Republic of Georgia; SG, Singapore; UK, United Kingdom; UPMC, University of Pittsburgh Medical Center; US, United States.

[a] Multinationality survey among HCWs from Saudi Arabia, South Africa, UK, and US.

[b] This is the average vaccination coverage. By location, the vaccination coverage is as follows: 14% in HK, 36% in SG, 41% in UK.

[c] This is the average vaccination coverage. By year, the vaccination coverage was 52% in 2000 and 75% in 2004.

TABLE 2. Factors Associated with Vaccination Acceptance or Refusal by Study

Study	Vaccine	Nurses	Physicians	Age	Sex	Cost	Convenience	Self-protection	Patient protection	Family/friends protection	Risk of disease	Risk of disease from vaccine	Vaccine safety	Vaccine efficacy
Al-Tawfiq et al[26]	Seasonal influenza			Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes		
Arda et al[28]	Pandemic influenza A (H1N1)	Yes		Yes	Yes						Yes			
Barrière et al[29]	Pandemic influenza A (H1N1)	Yes		Yes										
Bautista et al[30]	Seasonal influenza	Yes	Yes							Yes	Yes		Yes	Yes
Beguin et al[23]	Seasonal influenza		Yes					Yes						Yes
Briggs et al[31]	Hepatitis B			Yes	Yes						Yes			Yes
Chor et al[25]	Pandemic influenza A (H1N1)	Yes									Yes			
Christini et al[32]	Seasonal influenza	Yes	Yes											
Doebbeling et al[33]	Seasonal influenza		Yes	Yes										
Everett et al[34]	Smallpox										Yes		Yes	
Fowler et al[35]	Anthrax			Yes	Yes						Yes		Yes	Yes
Goins et al[36]	Pertussis	Yes	Yes								Yes		Yes	
Heimberger et al[37]	Seasonal influenza		Yes	Yes	Yes							Yes		
LaVela et al[38]	Seasonal influenza	Yes		Yes	Yes									Yes
Lee et al[39]	Hepatitis B			Yes										
Lester et al[40]	Seasonal influenza			Yes	Yes									
Manuel et al[41]	Seasonal influenza						Yes	Yes		Yes		Yes		Yes
Martinello et al[42]	Seasonal influenza	Yes	Yes											
Nichol et al[43]	Seasonal influenza		Yes						Yes		Yes		Yes	Yes
Norton et al[44]	Seasonal influenza	Yes					Yes						Yes	
Nowalk et al[45]	Seasonal influenza											Yes		Yes
O'Reilly et al[46]	Seasonal influenza								Yes		Yes	Yes		Yes
Panhotra et al[47]	Hepatitis B	Yes	Yes		Yes									
Pareek et al[22]	Influenza A (H5N1)							Yes	Yes		Yes			
Piccirillo et al[48]	Seasonal influenza				Yes	Yes						Yes		
Qureshi et al[24]	Seasonal influenza				Yes						Yes			Yes
Rubin et al[49]	Seasonal influenza and pandemic influenza A (H1N1)										Yes			
Saluja et al[50]	Seasonal influenza		Yes	Yes	Yes									
Seale et al[51]	Seasonal influenza and influenza A (H1N1)	Yes	Yes		Yes									Yes
Song et al[52]	Seasonal influenza	Yes	Yes			Yes							Yes	
Steiner et al[53]	Seasonal influenza				Yes									
Takayanagi et al[54]	Seasonal influenza			Yes										
Topuridze et al[55]	Hepatitis B	Yes		Yes	Yes						Yes		Yes	
Trivalle et al[56]	Seasonal influenza	Yes	Yes	Yes	Yes			Yes	Yes		Yes	Yes		Yes
Walker et al[57]	Seasonal influenza			Yes	Yes									
Weingarten et al[58]	Seasonal influenza	Yes	Yes											
Yanturali et al[59]	Smallpox				Yes						Yes		Yes	

TABLE 3. Results

Factor	No. of studies	Pooled OR	95% CI	P	Q statistic P	Publication bias P
Demographic						
Employment as a nurse[25,28-30,32,36,38,42,44,47,51,52,55,56,58]	15	0.66	0.46–0.97	.033	<.001	<.001
Employment as a physician[23,30,32,33,36,37,42,43,47,50-52,56,58]	14	1.61	0.97–2.67	.065	<.001	.390
Older age[26,28,29,31,33,35,37-40,50,54-57]	15	1.06	0.76–1.48	.739	<.001	.621
Female sex[24,26,28,31,35,37,38,40,47,48,50,51,53,55-57,59]	17	0.91	0.76–1.08	.273	<.001	.926
Perceived benefits						
Self-protection[22,23,26,41,56]	5	3.42	2.42–4.82	<.001	.71	.202
Prevent illness in patients[22,26,41,43,46,56]	6	2.96	1.49–5.96	.002	<.001	.021
Prevent illness in family or friends[30,41]	2	3.28	1.10–9.75	.033	.15	...
Perceived risks						
Acquiring the disease[22,24-26,28,30,31,34-36,43,46,49,55,56,59]	16	1.74	1.30–2.33	<.001	<.001	.047
Disease from vaccination[26,37,41,45,46,48,56]	7	0.42	0.30–0.58	<.001	.10	.966
Vaccine unsafe[30,34-36,43,44,52,55,59]	9	0.51	0.32–0.83	.006	<.001	.021
Perceived efficacy of vaccine						
Belief that vaccine is effective[23,24,30,31,35,38,41,43,45,46,51,56]	12	2.26	1.62–3.16	<.001	<.001	.175
Cost and convenience						
Provision of vaccines free of charge[26,48,52]	3	4.70	2.32–9.51	<.001	.025	.210
Convenient access to vaccination[26,41,44]	3	13.83	0.78–246.75	.074	<.001	.784

NOTE. CI, confidence interval; OR, odds ratio.

the source population (eg, appeared to be selected in an unbiased manner, with high response rates for surveys), (4) attempt made to adjust for confounding, (5) attempt made to validate survey responses to institutional records where possible, and (6) discussion of study limitations. Each criterion was scored as 1 (yes) or 0 (no), and by summing up the scores, each study was classified as high quality (5+ points), moderate quality (3–4 points), or poor quality (<3 points). Study quality was graded independently by 2 authors (M.V. and D.N.F.). Results were compared and disagreements resolved through discussion.

Conceptual Framework

Factors associated with acceptance or rejection of vaccination were grouped under 5 major headings that were devised a priori and are specific to vaccination but are closely related to the conceptual model of compliance described by Becker and Maiman.[17] These included (1) demographic and occupational characteristics (eg, age, sex, or job type), (2) facilitators such as convenience and cost (eg, time required for vaccination, introduction of mobile vaccine carts, and vaccines provided free of charge), (3) perceived benefits to self and others associated with vaccination (desire to protect self, patients, and family/friends), (4) barriers such as perceived risk of acquiring disease and perceived risk of acquiring disease as a result of vaccination or perceived safety of vaccine, and (5) perceived efficacy of vaccine (the association between healthcare worker belief in vaccine efficacy and their inclination to be vaccinated).

Meta-analysis

When quantitative data were sufficient for estimation of ORs for factors favoring vaccine acceptance or rejection (eg, raw data sufficient for construction of a 2 × 2 table; estimates of relative risk accompanied confidence intervals), we incorporated such data into summary pooled estimates of ORs using random-effects models.[18] When adjusted ORs or relative risks were available, these were used preferentially.

Evidence of between-study heterogeneity was assessed using the Q statistic of DerSimonian and Laird.[19] Although summary ORs were calculated in the presence of significant ($P < .05$) between-study heterogeneity, such estimates should be interpreted with caution. Sources of heterogeneity were explored in subgroup analyses and using meta-regression techniques.[20] We explored geographical region (Europe, Asia, or North America, which accounted for most included studies) as a potential source of heterogeneity of effects through stratified analyses and construction of meta-regression models for worker characteristics and perceptions of interest. We used similar methods to evaluate heterogeneity related to vaccine type (seasonal influenza, pandemic influenza, or non-influenza vaccines), publication year, and study quality.

Finally, we anticipated publication bias because we expected published studies to be more likely to present data suitable for inclusion in meta-analyses when statistically significant effects were observed (eg, it was our expectation that null effects would be commonly described as such, without inclusion of quantitative data). We explored the presence of publication bias graphically by constructing a funnel plot of relative risk and study variance and statistically using Egger's regression asymmetry plot.[21]

RESULTS

A total of 7,002 citations were retrieved using the search strategy described above. Review of titles and abstracts resulted in 116 studies being retrieved and reviewed in full (Figure 1). Of these,

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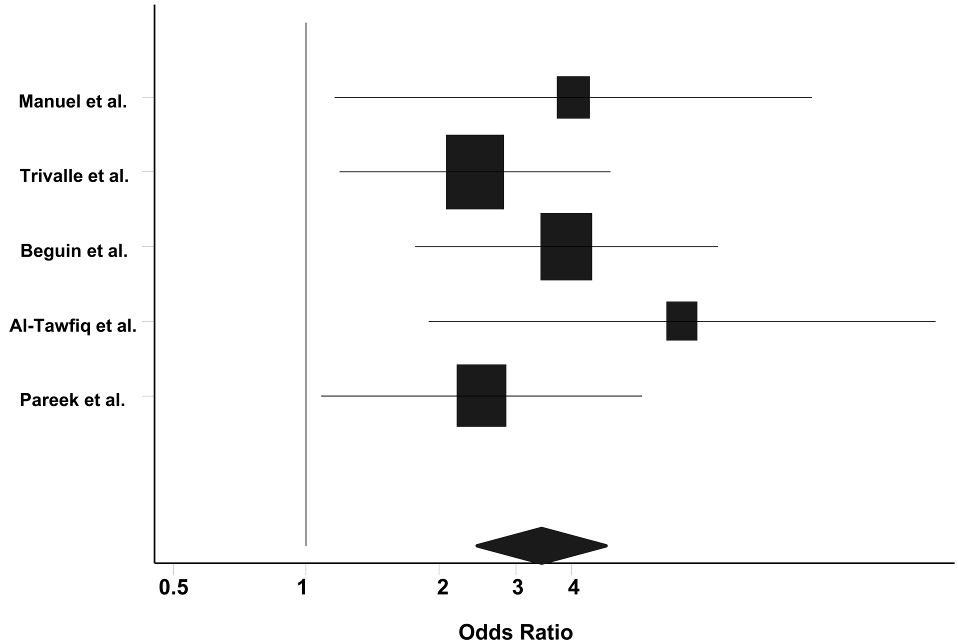

FIGURE 2. Forest plot of odds ratio (OR) of self protection as a factor associated with healthcare worker willingness to accept vaccination. Area of boxes is proportional to inverse of study variance. Horizontal lines represent 95% confidence intervals (CIs). Diamond represents summary estimate of ORs and confidence limits (OR, 3.42 [95% CI, 2.42–4.82]). Vertical line represents OR = 1. *X*-axis is on a log scale.

53 were excluded because they did not meet the inclusion criteria. Three additional studies were identified from the reference lists of the retrieved articles.[22-24] A total of 37 articles met the criteria for further analysis. Table 1 presents the characteristics of all studies included in our systematic review and meta-analysis.

Eligible studies were published from 1989 through May 2012. Nine of the studies were conducted in Europe, 20 in North America, 5 in Asia, and 1 in South America. One study recruited healthcare workers from 3 locations (Hong Kong, Singapore, and Leicester),[25] and 1 study was conducted in Saudi Arabia but included healthcare workers of several nationalities.[26] Twenty-three of 37 (62%) studies evaluated factors associated with seasonal influenza vaccine uptake; 3 focused on influenza A (H1N1) p2009, and 2 studies evaluated factors associated with both seasonal influenza and influenza A (H1N1) p2009 vaccine uptake; 1 study focused on highly pathogenic avian influenza A (H5N1), 2 on smallpox, and 4 on hepatitis B vaccination uptake. The remaining 2 studies evaluated pertussis boosting and anthrax vaccination. Eleven studies out of 37 were assessed as high quality, 22 as moderate quality, and 4 as poor quality, on the basis of the described quality assessment criteria above. All factors associated with acceptance or rejection of vaccination, investigated by study, are presented in Table 2.

The results of our meta-analysis are presented in Table 3. Although numerous factors appeared to be associated with the choice to receive vaccination, many factors were associated with significant heterogeneity across studies; consequently, pooled estimates of effect should be interpreted with caution. All 3 factors that were significantly and homogeneously associated with the decision to accept vaccination related to protection of one's self and/or one's family or friends: desire for self-protection (pooled OR, 3.42 [95% CI, 2.42–4.82]; Figure 2), desire to prevent illness in family or friends (pooled OR, 3.28 [95% CI, 1.10–9.75]), and perception that the vaccine itself may cause the disease it is intended to prevent (pooled OR, 0.42 [95% CI, 0.30–0.58]; Figure 3). While desire to prevent illness in patients was associated with increased likelihood of vaccine acceptance (pooled OR, 2.96 [95% CI, 1.49–5.96]), there was significant heterogeneity in this effect across studies (Q statistic $P = .002$). However, exploration of meta-influence plots suggested that a single study (by Pareek et al)[22] explained most between-study heterogeneity. When this study was removed, the effect of patient protection increased (pooled OR, 4.11 [95% CI, 3.12–5.41]), and estimates were no longer heterogeneous (Q statistic, 2.01 on 4 df; $P = .73$).

Perceived risk of disease in the absence of vaccination, belief that the vaccine itself is safe, and belief that the vaccine is effective (Figure 4) also appeared to influence desire to receive vaccination, though these estimates were heterogeneous, and vaccine safety effects showed evidence of publication bias ($P = 0.021$). Efforts to enhance convenience of vaccination were not significantly associated with acceptance, while free vaccine provision was, but again, these estimates were heterogeneous, and pooled estimates of effect should be interpreted with caution. Among demographic and employ-

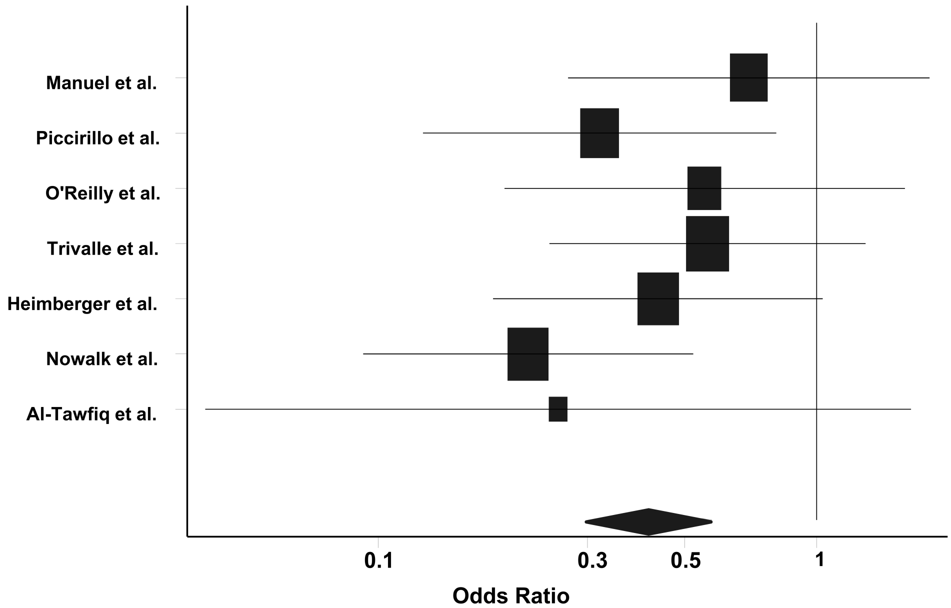

FIGURE 3. Forest plot of odds ratio (OR) of the perceived risk of contracting the disease as a result of vaccination as a factor associated with healthcare worker willingness to accept vaccination. Area of boxes is proportional to inverse of study variance. Horizontal lines represent 95% confidence intervals (CIs). Diamond represents summary estimate of ORs and confidence limits (OR, 0.42 [95% CI, 0.30–0.58]). Vertical line represents OR = 1. *X*-axis is on a log scale.

ment-related factors, only employment as a nurse appeared to predict decreased vaccine uptake (pooled OR, 0.66 [95% CI, 0.46–0.97]), but this estimate was heterogeneous (Q statistic $P < .001$), and Egger's test was also suggestive of publication bias ($P < .001$; ie, small studies that found decreased acceptance of vaccines by nurses were more likely to be published than expected, on the basis of mean effects).

Explorations of heterogeneity of effects by geographical region suggested that in Asian studies, nurses were more likely to accept vaccine, while physicians appeared less likely to accept vaccine, relative to European and North American studies (relative odds of acceptance by nurses in Asian studies, 2.29 [95% CI, 1.03–5.07]; relative odds of acceptance by physicians in Asian studies, 0.30 [95% CI, 0.13–0.70]). No other geographic variation in effects was seen.

When we explored influenza vaccination (seasonal, pandemic, or both) versus noninfluenza vaccination as a source of heterogeneity in estimates of effect, we failed to find significant differences in effects across studies. Among studies that evaluated the desire to protect patients as a predictor of acceptance of influenza vaccination, all between-study heterogeneity in effects could be attributed to differences between seasonal influenza vaccine and pandemic influenza vaccine. For the former, patient protection was a strong predictor of vaccine acceptance (pooled OR, 4.11 [95% CI, 3.12–5.40]; for heterogeneity, $P = .73$). This effect was not seen for pandemic vaccine (OR, 0.67 [95% CI, 0.41–1.10]).

We did not identify any contribution of year of publication to between-study heterogeneity in effects. In meta-regression analyses evaluating study quality, we found that high-quality studies identified decreased acceptance of immunization by nurses (OR, 0.44 [95% CI, 0.24–0.81]) as compared with low-quality studies (OR, 0.82 [95% CI, 0.53–1.27]; for difference in effects, $P = .033$), but significant heterogeneity remained in both high- and low-quality strata. No differences were seen between high- and low-quality studies for any other characteristic.

DISCUSSION

We performed a comprehensive, quantitative systematic review of factors that contribute to healthcare workers' decisions to accept vaccination. While our ability to draw firm conclusions across domains is hampered by between-study heterogeneity, we were able to identify several clear and consistent predictors of vaccine acceptance. Key among these was a belief by healthcare workers that vaccines would protect them and their families and that vaccines would be safe and, in particular, would not cause the disease they were meant to prevent. This latter concern is not uncommonly voiced with reference to influenza vaccines.[11]

We also found a statistically significant association between a desire to protect patients and willingness to accept vaccination and noted that heterogeneity in this effect appeared to be driven by a single outlying study. Emphasis on protective effects of vaccines for workers, their families, and patients may thus constitute an important key message for immunization promotion programs in the healthcare setting. With

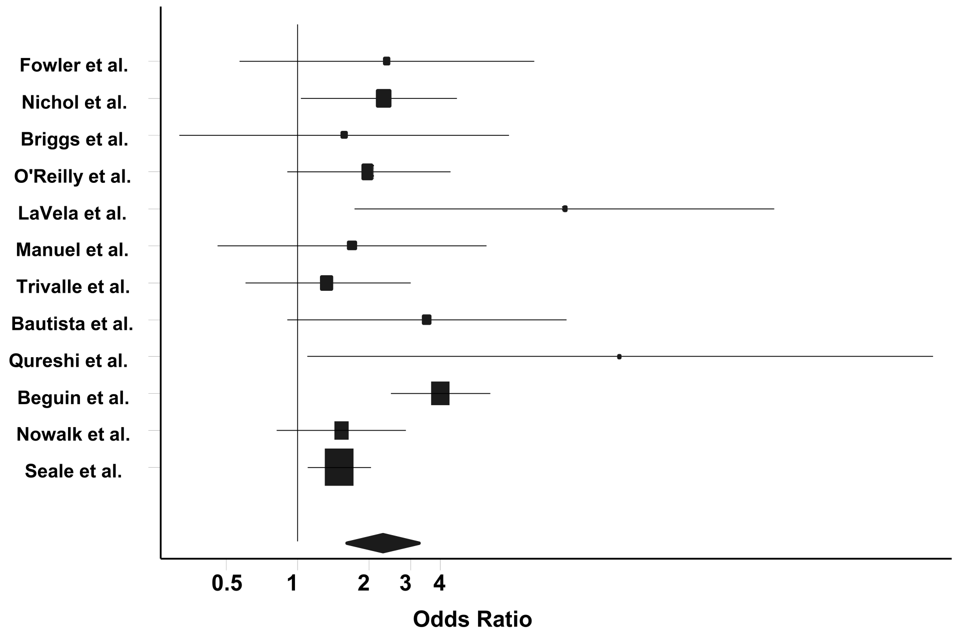

figure 4. Forest plot of odds ratio (OR) of vaccine efficacy as a factor associated with healthcare worker willingness to accept vaccination. Area of boxes is proportional to inverse of study variance. Horizontal lines represent 95% confidence intervals. Diamond represents summary estimate of ORs and confidence limits. Pooled estimate should be interpreted with caution because of substantial between-study heterogeneity in effects (OR, 2.26 [95% CI, 1.62–3.16]). Vertical line represents OR = 1. *X*-axis is on a log scale.

respect to the singular importance of self-protection as a driver of vaccine acceptance, our study is consistent with the findings of other systematic reviews that have been restricted to influenza vaccine.[10,11] For example, in a study that attempted to weigh qualitative concerns voiced by healthcare workers deciding whether to accept influenza vaccination, Hollemeyer et al[11] found that interest in self-protection was by far the most prominent driver of vaccine acceptance, with patient protection given less weight.

We do not wish to imply that correct messaging along a single domain will ensure optimal uptake of vaccination by healthcare workers. Multidomain strategies (eg, the combination of education, messaging related to self-protection, and convenience-enhancing measures such as mobile carts) may result in effects on vaccine uptake that are greater than would be expected on the basis of the combined effects of individual domains.[27]

We did identify important geographical heterogeneity in effects in meta-regression analyses, particularly with respect to the tendency of physicians and nurses to accept immunization. This highlights the importance of vaccine promotion programs that take into account the nuances in behavior and culture that may exist in a given country or region rather than "one size fits all" approaches to enhancing vaccination uptake.

Like any systematic review, our study is subject to limitations. In particular, variability in study designs, populations, and measurements is likely responsible for the statistical heterogeneity in effects that we observed in most domains. We were able to explore influenza vaccination versus other types of vaccination and global regions as possible sources of heterogeneity, but the breadth of our review made such evaluations for all possible study characteristics—and all possible factors enhancing uptake—impractical. We regard this as a potential area for future study. We did identify evidence of publication bias, particularly with reference to studies that reported increased risk of vaccine refusal by nurses and perceived lack of safety related to vaccines. Furthermore, the quality of our pooled estimates must, out of necessity, reflect the varying quality of included studies. Because studies were observational in nature, there exists the possibility of residual confounding in estimates used for pooling. Because of concerns about possible ecological fallacy, we excluded studies that looked at aggregate—rather than individual—vaccine uptake. Because healthcare workers are aware of the expectation of vaccine acceptance, and because studies evaluated self-reported preferences, studies may be subject to social desirability biases, with workers stating that they would accept vaccination when in reality they would not. Finally, the Centers for Disease Control and Prevention now define healthcare personnel to include students, trainees, and volunteers. We do not believe any included study evaluated students or volunteers; consequently, our results are not applicable to these populations.

In summary, we performed a systematic quantitative review of factors associated with vaccine acceptance by healthcare workers across a broad array of vaccine types. Our findings echo those of recent reviews that have focused on influenza vaccine, particularly the strength and consistency of self-protection as opposed to patient protection as a driver of vaccine uptake. These data may be helpful in the ongoing design and refinement of healthcare worker immunization programs.

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Address correspondence to David N. Fisman, MD, MPH, FRCPC, Dalla Lana School of Public Health, University of Toronto, 155 College Street, Room 547, Toronto, Ontario M5T 3M7, Canada (david.fisman@utoronto.ca).

REFERENCES

1. Halasa NB, Williams JV, Wilson GJ, Walsh WF, Schaffner W, Wright PF. Medical and economic impact of a respiratory syncytial virus outbreak in a neonatal intensive care unit. *Pediatr Infect Dis J* 2005;24(12):1040–1044.
2. Salgado CD, Giannetta ET, Hayden FG, Farr BM. Preventing nosocomial influenza by improving the vaccine acceptance rate of clinicians. *Infect Control Hosp Epidemiol* 2004;25(11):923–928.
3. Outbreaks of pertussis associated with hospitals–Kentucky, Pennsylvania, and Oregon, 2003. *MMWR Morb Mortal Wkly Rep* 2005;54(3):67–71.
4. Hyde TB, Gilbert M, Schwartz SB, et al. Azithromycin prophylaxis during a hospital outbreak of *Mycoplasma pneumoniae* pneumonia. *J Infect Dis* 2001;183(6):907–912.
5. Ofner-Agostini M, Gravel D, McDonald LC, et al. Cluster of cases of severe acute respiratory syndrome among Toronto healthcare workers after implementation of infection control precautions: a case series. *Infect Control Hosp Epidemiol* 2006; 27(5):473–478.
6. Maltezou HC. Nosocomial influenza: new concepts and practice. *Curr Opin Infect Dis* 2008;21(4):337–343.
7. Carman WF, Elder AG, Wallace LA, et al. Effects of influenza vaccination of health-care workers on mortality of elderly people in long-term care: a randomised controlled trial. *Lancet* 2000; 355 (9198):93–97.
8. Wilde JA, McMillan JA, Serwint J, Butta J, O'Riordan MA, Steinhoff MC. Effectiveness of influenza vaccine in health care professionals: a randomized trial. *JAMA* 1999;281(10):908–913.
9. Rea E, Upshur R. Semmelweis revisited: the ethics of infection prevention among health care workers. *CMAJ* 2001;164(10): 1447–1448.
10. Hofmann F, Ferracin C, Marsh G, Dumas R. Influenza vaccination of healthcare workers: a literature review of attitudes and beliefs. Infection 2006;34(3):142–147.
11. Hollmeyer H, Hayden F, Poland G, Buchholz U. Influenza vaccination of health care workers in hospitals: a review of studies on attitudes and predictors. *Vaccine* 2009;27:3935–3944.
12. Riphagen-Dalhuisen J, Gefenaite G, Hak E. Predictors of seasonal influenza vaccination among healthcare workers in hospitals: a descriptive meta-analysis. *Occup Environ Med* 2012; 69(4):230–235.
13. Diodati C. Mandatory vaccination of health care workers. *CMAJ* 2002;166(3):301–302.
14. Abramson ZH. What, in fact, is the evidence that vaccinating healthcare workers against seasonal influenza protects their patients? a critical review. *Int J Family Med* 2012;2012:205464.
15. Yassi A, Lockhart K, Buxton JA, McDonald I. Vaccination of health care workers for influenza: promote safety culture, not coercion. *Can J Public Health* 2010;101(suppl 1):S41–S45.
16. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health* 1998;52(6):377–384.
17. Becker MH, Maiman LA. Sociobehavioral determinants of compliance with health and medical care recommendations. *Med Care* 1975;13(1):10–24.
18. Deeks JJ, Altman DG. Effect measures for meta-analysis of trials with binary outcomes. In: Egger M, Smith GD, Altman DG, eds. *Systematic Reviews in Health Care*. London: BMJ, 2008:313–335.
19. Deeks JJ, Altman DG, Bradburn MJ. Statistical methods for examining heterogeneity and combining results from several studies in meta-analysis. In: Egger M, Smith GD, Altman DG, eds. *Systematic Reviews in Health Care*. London: BMJ, 2008:285–312.
20. Smith GD, Egger M. Going beyond the grand mean: subgroup analysis in meta-analysis of randomised trials. In: Egger M, Smith GD, Altman DG, eds. *Systematic Reviews in Health Care*. London: BMJ, 2008:143–156.
21. Sterne JAC, Egger M, Smith GD. Investigating and dealing with publication and other biases in meta-analysis. *BMJ* 2001; 323(7304):101–105.
22. Pareek M, Clark T, Dillon H, Kumar R, Stephenson I. Willingness of healthcare workers to accept voluntary stockpiled H5N1 vaccine in advance of pandemic activity. *Vaccine* 2009;27(8): 1242–1247.
23. Beguin C, Boland B, Ninane J. Health care workers: vectors of influenza virus? low vaccination rate among hospital health care workers. *Am J Med Qual* 1998;13(4):223–227.
24. Qureshi AM, Hughes NJM, Murphy E, Primrose WR. Factors influencing uptake of influenza vaccination among hospital-based health care workers. *Occup Med* 2004;54(3):197–201.
25. Chor JSY, Pada SK, Stephenson I, et al. Seasonal influenza vaccination predicts pandemic H1N1 vaccination uptake among healthcare workers in three countries. *Vaccine* 2011;29(43):7364–7369.
26. Al-Tawfiq JA, Antony A, Abed MS. Attitudes towards influenza vaccination of multi-nationality health-care workers in Saudi Arabia. *Vaccine* 2009;27(40):5538–5541.
27. Lam P, Chambers L, MacDougall D, McCarthy A. Seasonal influenza vaccination campaigns for health care personnel: systematic review. *CMAJ* 2010;182(12):E542–E548.
28. Arda B, Durusoy R, Yamazhan T, et al. Did the pandemic have an impact on influenza vaccination attitude? a survey among health care workers. *BMC Infect Dis* 2011;11(1):87.
29. Barrière J, Vanjak D, Kriegel I, et al. Acceptance of the 2009 A(H1N1) influenza vaccine among hospital workers in two French cancer centers. *Vaccine* 2010;28(43):7030–7034.
30. Bautista D, Vila B, Usó R, Téllez M, Zanón V. Predisposing,

reinforcing, and enabling factors influencing influenza vaccination acceptance among healthcare workers. *Infect Control Hosp Epidemiol* 2006;27(1):73–77.
31. Briggs MJ, Thomas J. Obstacles to hepatitis B vaccine uptake by health care staff. *Public Health* 1994;108(2):137–148.
32. Christini AB, Shutt KA, Byers KE. Influenza vaccination rates and motivators among healthcare worker groups. *Infect Control Hosp Epidemiol* 2007;28(2):171–177.
33. Doebbeling BN, Edmond MB, Davis CS, Woodin JR, Zeitler RR. Influenza vaccination of health care workers: evaluation of factors that are important in acceptance. *Prev Med* 1997;26(1):68–77.
34. Everett WW, Zaoutis TL, Halpern SD, Strom BL, Coffin SE. Preevent vaccination against smallpox: a survey of pediatric emergency health care providers. *Pediatr Infect Dis J* 2004;23(4):332–337.
35. Fowler GL, Baggs JM, Weintraub ES, Martin SW, McNeil MM, Gust DA. Factors influencing laboratory workers' decisions to accept or decline anthrax vaccine adsorbed (AVA): results of a decision-making study in CDC's anthrax vaccination program. *Pharmacoepidemiol Drug Saf* 2006;15(12):880–888.
36. Goins WP, Schaffner W, Edwards KM, Talbot TR. Healthcare workers' knowledge and attitudes about pertussis and pertussis vaccination. *Infect Control Hosp Epidemiol* 2007;28(11):1284–1289.
37. Heimberger T, Chang H-G, Shaikh M, Crotty L, Morse D, Birkhead G. Knowledge and attitudes of healthcare workers about influenza: why are they not getting vaccinated? *Infect Control Hosp Epidemiol* 1995;16(7):412–415.
38. LaVela SL, Smith B, Weaver FM, Legro MW, Goldstein B, Nichol K. Attitudes and practices regarding influenza vaccination among healthcare workers providing services to individuals with spinal cord injuries and disorders. *Infect Control Hosp Epidemiol* 2004;25(11):933–940.
39. Lee DJ, Carrillo L, Fleming L. Epidemiology of hepatitis B vaccine acceptance among urban paramedics and emergency medical technicians. *Am J Infect Control* 1997;25(5):421–423.
40. Lester RT, McGeer A, Tomlinson G, Detsky AS. Use of, effectiveness of, and attitudes regarding influenza vaccine among house staff. *Infect Control Hosp Epidemiol* 2003;24(11):839–844.
41. Manuel DG, Henry B, Hockin J, Naus M. Health behavior associated with influenza vaccination among healthcare workers in long-term-care facilities. *Infect Control Hosp Epidemiol* 2002;23(10):609–614.
42. Martinello R, Jones L, Topal J. Correlation between healthcare workers' knowledge of influenza vaccine and vaccine receipt. *Infect Control Hosp Epidemiol* 2003;24:845–847.
43. Nichol KL, Hauge M. Influenza vaccination of healthcare workers. *Infect Control Hosp Epidemiol* 1997;18(3):189–194.
44. Norton SP, Scheifele DW, Bettinger JA, West RM. Influenza vaccination in paediatric nurses: cross-sectional study of coverage, refusal, and factors in acceptance. *Vaccine* 2008;26(23):2942–2948.
45. Nowalk M, Lin C, Zimmerman R, et al. Self-reported influenza vaccination rates among health care workers in a large health system. *Am J Infect Control* 2008;36(8):574–581.
46. O'Reilly FW, Cran GW, Stevens AB. Factors affecting influenza vaccine uptake among health care workers. *Occup Med* 2005;55(6):474–479.
47. Panhotra BR, Saxena AK, Al-Hamrani HA, Al-Mulhim A. Compliance to hepatitis B vaccination and subsequent development of seroprotection among health care workers of a tertiary care center of Saudi Arabia. *Am J Infect Control* 2005;33(3):144–150.
48. Piccirillo B, Gaeta T. Survey on use of and attitudes toward influenza vaccination among emergency department staff in a New York metropolitan hospital. *Infect Control Hosp Epidemiol* 2006;27(6):618–622.
49. Rubin GJ, Potts HWW, Michie S. Likely uptake of swine and seasonal flu vaccines among healthcare workers: a cross-sectional analysis of UK telephone survey data. *Vaccine* 2011;29(13):2421–2428.
50. Saluja I, Theakston KD, Kaczorowski J. Influenza vaccination rate among emergency department personnel: a survey of four teaching hospitals. *Can J Emerg Med* 2005;7(1):17–21.
51. Seale H, Kaur R, Wang Q, et al. Acceptance of a vaccine against pandemic influenza A (H1N1) virus amongst healthcare workers in Beijing, China. *Vaccine* 2011;29(8):1605–1610.
52. Song JY, Park CW, Jeong HW, Cheong HJ, Kim WJ, Kim SR. Effect of a hospital campaign for influenza vaccination of healthcare workers. *Infect Control Hosp Epidemiol* 2006;27(6):612–617.
53. Steiner MP, Vermeulen LCRMS, Mullahy JP, Hayney MSSP. Factors influencing decisions regarding influenza vaccination and treatment: a survey of healthcare workers. *Infect Control Hosp Epidemiol* 2002;23(10):625–627.
54. Takayanagi IJ, Cardoso MRA, Costa SF, Araya MES, Machado CM. Attitudes of health care workers to influenza vaccination: why are they not vaccinated? *Am J Infect Control* 2007;35(1):56–61.
55. Topuridze M, Butsashvili M, Kamkamidze G, Kajaia M, Morse D, McNutt LA. Barriers to Hepatitis B vaccine coverage among healthcare workers in the Republic of Georgia: an international perspective. *Infect Control Hosp Epidemiol* 2010;31(2):158–164.
56. Trivalle C, Okenge E, Hamon B, Taillandier J, Falissard B. Factors that influence influenza vaccination among healthcare workers in a French geriatric hospital. *Infect Control Hosp Epidemiol* 2006;27(11):1278–1280.
57. Walker FJ, Singleton JA, Lu P, Wooten KG, Strikas RA. Influenza vaccination of healthcare workers in the United States, 1989–2002. *Infect Control Hosp Epidemiol* 2006;27(3):257–265.
58. Weingarten S, Riedinger M, Bolton LB, Miles P, Ault M. Barriers to influenza vaccine acceptance: a survey of physicians and nurses. *Am J Infect Control* 1989;17(4):202–207.
59. Yanturali S, Suner S, Aksay E, Cevik AA, Sonmez Y. To be vaccinated or not? a survey of Turkish emergency physicians regarding smallpox. *J Emerg Med* 2005;28(2):139–145.