ORIGINAL ARTICLE

Prevention of Needle-Stick Injuries in Healthcare Facilities: A Meta-Analysis

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OBJECTIVE. To estimate the summary effectiveness of different needle-stick injury (NSI)-prevention interventions.

DESIGN. We conducted a meta-analysis of English-language articles evaluating methods for reducing needle stick, sharp, or percutaneous injuries published from 2002 to 2012 identified using PubMed and Medline EBSCO databases. Data were extracted using a standardized instrument. Random effects models were used to estimate the summary effectiveness of 3 interventions: training alone, safety-engineered devices (SEDs) alone, and the combination of training and SEDs.

SETTING. Healthcare facilities, mainly hospitals

PARTICIPANTS. Healthcare workers including physicians, midwives, and nurses

RESULTS. From an initial pool of 250 potentially relevant studies, 17 studies met our inclusion criteria. Six eligible studies evaluated the effectiveness of training interventions, and the summary effect of the training intervention was 0.66 (95% CI, 0.50–0.89). The summary effect across the 5 studies that assessed the efficacy of SEDs was 0.51 (95% CI, 0.40–0.64). A total of 8 studies evaluated the effectiveness of training plus SEDs, with a summary effect of 0.38 (95% CI, 0.28–0.50).

CONCLUSION. Training combined with SEDs can substantially reduce the risk of NSIs.

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Needle-stick injuries (NSIs) are a worldwide occupational health problem in the healthcare industry. In 2003, the World Health Organization (WHO) estimated that almost 3 million of 37 million healthcare workers (HCWs) experienced at least 1 NSI in the past year.[1] More than 25 blood-borne viruses have been reported following NSIs among HCWs or laboratory personnel, including human immunodeficiency virus (HIV), hepatitis C virus (HCV), and hepatitis B virus (HBV).[2]

In healthcare facilities, 3 broad intervention strategies are used to prevent NSIs: (1) training on safe injection procedures and proper use and disposal of sharps, commonly referred to as "universal or standard precautions";[3] (2) safety-engineered device (SED) controls, which include replacing "conventional" needles with safety needles and introducing containers for safety disposal of used needles; and (3) a combination of training and SEDs.

A large number of studies have been conducted to evaluate the effectiveness of these interventions, including several systematic reviews.[4–6] However, to our knowledge, no recent systematic review has quantitatively summarized the effectiveness of training and/or SEDs for reducing NSIs. The goal of this study was therefore to conduct a meta-analysis to produce quantitative summary estimates of the effectiveness of NSI-prevention interventions.

METHODS

Inclusion Criteria for Selected Published Studies

The proposed work included all peer-reviewed English-language research articles published between January 1, 2002, and December 31, 2012, that quantitatively estimated the effectiveness for 1 of 3 types of preventive measures: training alone, SEDs alone, or a combination of training and SEDs. Articles were limited to those reporting NSIs, ie, percutaneous or sharps injuries experienced by HCWs employed in healthcare facilities. Letters to the editor or studies reporting the experience of healthcare students (usually doctors or nurses in training) were excluded from the analysis. Included articles had to provide quantitative estimates of the interventions effectiveness as a ratio

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NOTE. Dr. Tarigan passed away suddenly on December 5, 2014, after completing this work and submitting the paper for publication. Dr. Tarigan was deeply committed to improving public health in Indonesia and his untimely passing is a great loss to his country. The coauthors dedicate this paper to his memory and to his family.

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measure of association, such as an incidence rate ratio or risk ratio, as absolute incidence rates, or as risks before and after the intervention.

Search Methods for Identifying the Published Studies

Articles were identified through keyword searches in PubMed and Medline EBSCO databases. The following search terms were used in searches of both databases: ("percu* injur*, needle* stick injur*, needlestick* injur*, or sharp* injur*), AND (intervene*, prevent*, reduc* or impact*, or educat*), AND (healthcare worker* or health care worker*), AND (rate*, risk* or ratio*). All of the identified articles were combined and saved in 1 file, excluding duplicates. The reference lists of eligible articles were then manually searched to identify any additional articles that were not captured by the PubMed or Medline EBSCO searches.

Selecting and Appraising Articles

The article appraisals were conducted by 2 authors (LT and DK). LT printed the titles and abstracts of all identified articles. Abstracts meeting the inclusion criteria were retained, and then discussed with DK to reach an agreement regarding which articles were potentially eligible for meta-analysis. The full-text of articles that met the inclusion criteria were then obtained and reappraised by both of these authors to confirm that each article met the inclusion criteria. Disagreements were resolved by discussion.

Information Extracted from the Articles

The following information was extracted from each eligible article: author(s) and publication year, study design, data source, intervention procedure, study population, sampling criteria and procedure, sample size, site of study, study period, outcome, case-finding mechanism, denominator for the injury rate (described below), and effect size.

Data Analysis

Articles were divided into 3 categories based on the type of intervention methods used: (1) training on standard precautions; (2) implementation of SEDs; or (3) a combination of training plus implementation of SEDs. Studies in each of these 3 types of interventions were independently analyzed. For studies using surveillance data with multiyear observation periods, the effect estimate of the intervention 1 year before compared with 1 year after intervention was used; the effect estimate "during" the year of intervention was not included in the analysis.

Studies that reported effects of different SEDs were treated as 1 study; we used the combined (total) effect of all types of safety devices for our analysis. For example, a single study measuring injuries caused by 3 different devices (eg, winged needles, catheters, and vacuum tubes) was treated as 1 study by calculating the combined effect across all 3 interventions. Also, if 1 study measured the effects of the intervention in different occupational groups, such as doctors and nurses, the effect across all occupational groups was used.

Effect Size and Precision

Quantitative effect estimates were reported in many different ways. Some studies used relative risks or rate ratios, while other studies reported the effect size using odds ratios, incidence rates, or risks. In the meta-analysis, we recalculated the effects in all studies as relative risks with appropriate 95% confidence intervals.

NSI rates can be calculated using a variety of different denominators, including the number of full-time equivalent workers (FTEs).[7] The FTE is a measure of the number of workers at risk, adjusted for the number of hours they work. FTE is typically calculated as the number of total person-hours worked by the population at risk divided by the number of hours worked per year by a single full-time worker, which is usually considered to be 2,000 hours. Some studies did not account for variability in hours worked, using simply the number of HCWs at risk.[8] NSI rates can also be calculated using various indicators of the expected numbers of injections performed by the at-risk population. For example, the number of patient days,[9] the number of occupied beds,[10] the number of sharps devices purchased,[11] and the number of sharps devices used[12,13] were all included in 1 or more studies as denominators for calculating NSI rates.

The studies did not provide the data required to recalculate all rates using the same denominator. Therefore, we evaluated effect measures (rate ratios) based on rates with different denominators. This method is not a serious limitation because the rate ratios are unitless quantities and tend to be less sensitive to differences in absolute magnitude than the rates themselves. We performed a subgroup analysis comparing the summary effects separately for the 2 different types of denominators (HCWs, SEDs) to investigate potential heterogeneity introduced by the denominators of the rates.

Summary of Effect Sizes

We used a random effects model to estimate summary effects.[14] The random effects model was chosen because the studies were drawn from populations and study designs that were reasonably assumed to be different from one another in important ways. In addition, subgroup analyses were performed for the 3 different interventions, as noted above, without considering the differences among rate denominators. Forest plots were constructed using a program by Neyeloff written for Microsoft Excel to provide visual summaries of the results.[15]

Measures of Heterogeneity

Using Microsoft Excel (Seattle, WA), 2 measures of heterogeneity (Q and I^2) were calculated.[15] The Q statistic tests the null hypothesis that all studies have the same true effect size and I^2 estimates the proportion of the total variability in effect sizes that can be attributed to between-study heterogeneity.[14] Higgins and Green[16] suggest that $I^2 < 40\%$ be interpreted as low heterogeneity, 30%–60% as moderate heterogeneity, 50%–90% as substantial heterogeneity, and 75%–100% as considerable heterogeneity.

RESULTS

Study Selection

Using the literature search terms listed above, 220 and 219 articles were identified from the Medline EBSCO and PubMed databases, respectively. These article lists were combined, and duplicate articles were excluded, yielding 250 articles for the review process. In total, 234 articles were excluded, leaving 16 articles for further analysis (Figure 1). In addition, 1 article was obtained through searching the references of the 16 eligible articles. Finally, 17 full-text articles were included in the quantitative meta-analysis.

Study Characteristics

We identified only 1 randomized controlled trial evaluating NSIs intervention.[17] All other studies reported the rates of NSI before and after implementation of 1 or more types of interventions. Most of the studies evaluated 1 type of intervention, either training, SEDs, or training plus SEDs; 2 studies evaluated both training and training plus SEDs. Furthermore, 2 other studies evaluated SEDs separately for 3 different types of SEDs: 1 study evaluated winged needles, vacuum tube collection, and catheters,[11] and 1 study evaluated winged needles, vacuum tube collection, and needles.[13] The content of training interventions varied from one study to another but usually covered standard precautions, unsafe practices that lead to NSIs, information on the diseases transmitted through NSIs, the importance of HBV vaccination, post-exposure prophylaxis (PEP), and safe disposal procedures. Most of the studies were conducted in Western countries, especially in the United States. We identified 3 studies conducted in developing countries,[18–20] although only 1 of these studies evaluated the effectiveness of SEDs.[19]

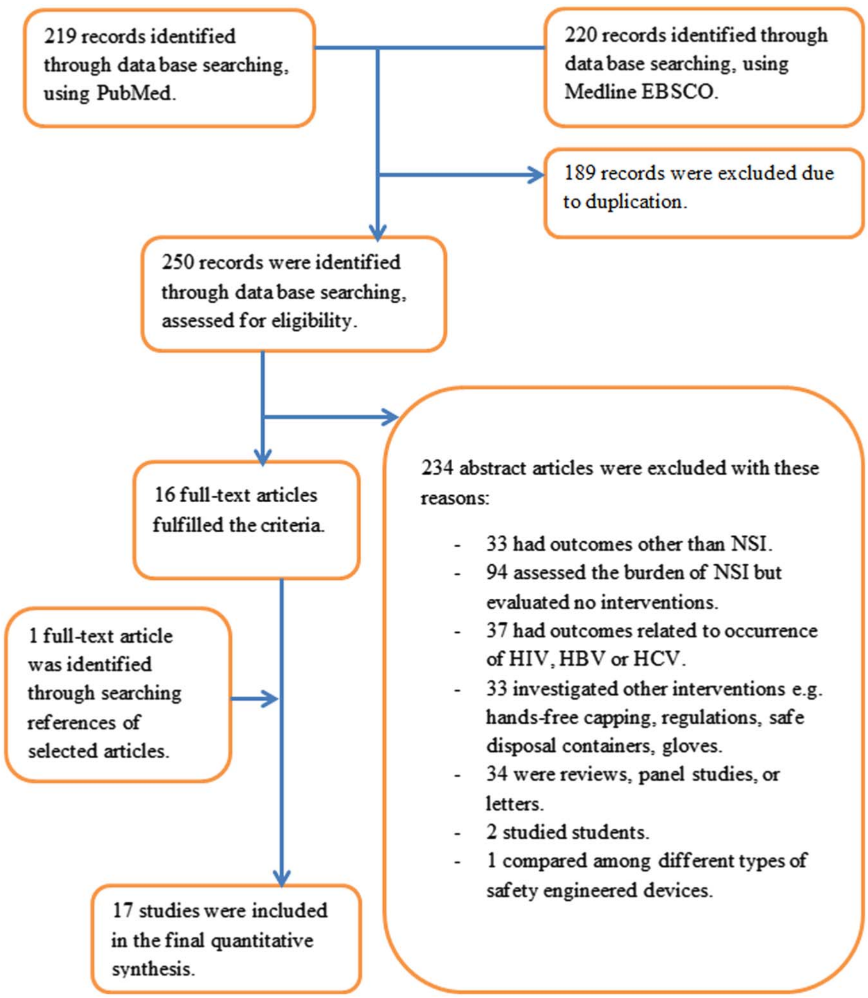

FIGURE 1. The flow of articles selected.

TABLE 1. Characteristics of the Selected Studies

Authors	Year Published	Type of Intervention	Country	Denominator
Mendelson et al[23]	2003	SEDs and training	USA	Devices used
Alvarado-Ramy et al[13]	2003	SEDs	USA	Devices used
Rogues et al[24]	2004	SEDs	France	Devices purchased
Sohn et al[25]	2004	SEDs	USA	FTE
Trape-Cardoso and Schenk[7]	2004	SEDs and training	USA	FTE
Moens et al[10]	2004	Training	Belgium	Occupied beds
Mobasherizadeh et al[19]	2005	SEDs and training	Iran	Health workers
Adams and Elliott[21]	2006	Training SEDs and training	UK	Devices used
Azar-Cavanagh et al[8]	2007	SEDs and training	USA	Health workers
Valls et al[9]	2007	SEDs and training	Spain	Patient-days
Lamontagne et al[11]	2007	SEDs	France	Devices purchased
Whitby et al[26]	2008	SEDs	Australia	FTE
Brusaferro et al[22]	2009	Training	Italy	Working hours
Zafar et al[20]	2009	Training	Pakistan	FTE
Sossai et al[12]	2010	SEDs and training	Italy	Devices used
Van der Molen et al[17]	2011	SEDs and training Training	Netherlands	Health workers
El Beltagy et al[18]	2012	Training	Saudi Arabia	Health workers

NOTE. SED, safety-engineered devices; FTE, full-time equivalent workers.

Study populations were defined in various ways, from the workers in 1 or a few hospital departments to employees of large hospital systems. There was also considerable variability in the total number of subjects, depending on the denominator used (Table 1). Study periods also varied from 12 months[17] to 10 years.[18] Most of the studies (59%) relied on data collected through an established surveillance system in which HCWs self-reported NSIs, whereas 41% of the studies relied on data collected by interviewers who contacted the participating HCWs and asked about their NSI experience over the previous 12 months. The studies we reviewed used 3 different definitions of the outcome being evaluated: NSIs, percutaneous injuries, and sharps injuries. These are closely related phenomena, and the overlap between them is considerable.

Summary Effects and Subgroup Analyses

All of the interventions (ie, training, SEDs, and a combination of training plus SEDs) appeared to have protective effects (Figure 2). The introduction of SEDs combined with training was associated with greater protection than training interventions alone. Individual study results for the effect of the training intervention on the rate of NSIs ranged from 0.41 to 0.85, meaning that the NSI rate after training was 41%–85% of the rate before the intervention. The reported reductions in the rates of NSI from SEDs were generally even stronger with individual study effects, ranging from 0.26 to 0.64. The combined effects of training plus SEDs ranged from 0.12 to 0.54.

A total of 6 studies evaluated the effectiveness of training interventions alone. All of these studies found protective effects. The summary effect of the training intervention was 0.66 (95% CI, 0.50–0.89). The Q-statistic was 54.4; df = 5; $P = .00$ with $I^2 = 90\%$. The former test indicates that the interstudy heterogeneity is too large to be likely due to chance alone, and the I^2 statistic also supports the finding of considerable interstudy heterogeneity.

The summary effect across the 5 studies that assessed the efficacy of SEDs alone was 0.51 (95% CI, 0.40–0.64). The Q-statistic was 8.5; df = 4; $P = .07$ with $I^2 = 53\%$. Unlike the summary effect for training, these statistics suggest a reasonable degree of homogeneity among the studies. A total of 8 studies evaluated the effectiveness of training plus SEDs. The summary effect was 0.38 (95% CI, 0.28–0.50). The Q-statistic was 9.4; df = 7; $P = .25$, and $I^2 = 26\%$. As with the SED interventions studies, this set of results appears to be reasonably homogeneous.

Subgroup Analyses for Alternative Denominators

We were concerned that the use of 3 different denominators for calculating NSI rates might have introduced important variability into the summary effect estimates. Overall, 4 studies evaluating the training plus SED intervention used the number of devices as the denominator, and another 4 studies used the number of HCWs as the denominator. The summary effects were somewhat different in these 2 subgroups. Using the number of devices, the summary effect size was OR = 0.54 (95% CI, 0.41–0.69); however, when the number of HCWs was the denominator, the summary effect was even stronger: OR = 0.35 (95% CI, 0.26–0.46). In both cases, the evidence was strong that the combination of training plus SEDs reduces the risk of NSI. All of the studies in the other 2 intervention subgroups used the same denominators; therefore, this sensitivity analysis could not be conducted for these subgroups.

Training	RR*	LCL	UCL
El Beltagy K, 2012	0.44	0.38	0.50
Van der Molen, H F. 2011	0.41	0.14	1.21
Zafar, Afia 2009	0.60	0.43	0.84
Brusaferro, S. 2009	0.41	0.28	0.61
Adams, D. 2006	0.83	0.36	1.95
Moens, G. 2004	0.85	0.75	0.95
Summary	**0.66**	**0.50**	**0.89**

Safety devices	RR	LCL	UCL
Whitby M, 2008	0.64	0.46	0.88
Lamontagne, F. 2007	0.26	0.13	0.51
Sohn, S. 2004	0.42	0.31	0.57
Rogues, A M. 2004	0.53	0.37	0.76
Alvarado-Ramy, F. 2003	0.60	0.45	0.79
Summary	**0.51**	**0.40**	**0.64**

Devices plus training	RR	LCL	UCL
Van der Molen, H. F. 2011	0.22	0.05	0.99
Sossai, Dimitri 2010	0.30	0.08	1.10
Valls, V. 2007	0.12	0.01	0.93
Azar-Cavanagh, M. 2007	0.25	0.09	0.67
Adams, D. 2006	0.29	0.09	0.91
Mobasherizadeh, S 2005	0.28	0.16	0.47
Trape-Cardoso, M. 2004	0.40	0.27	0.61
Mendelson, MH. 2003	0.54	0.41	0.72
Summary	**0.38**	**0.28**	**0.50**

* RR = Rate ratio
LCL = Lower confidence limit
UCL = Upper confidence limit

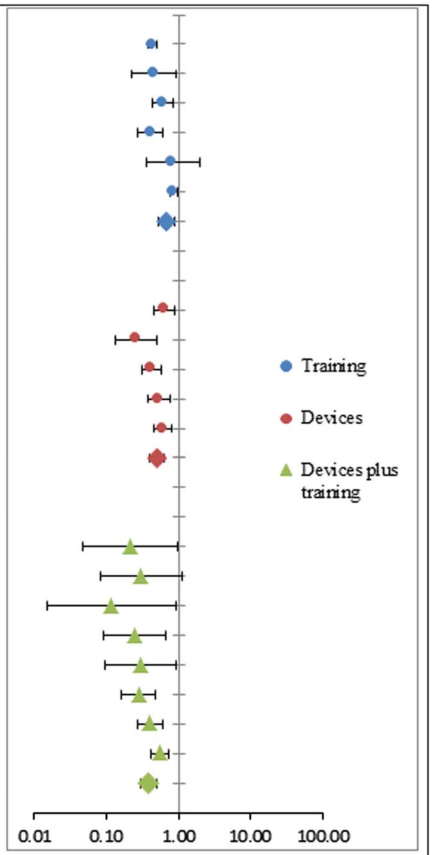

FIGURE 2. Forest plot of studies evaluating effects of 3 different interventions on the rate of needle-stick injuries.

DISCUSSION

The studies summarized here provide strong evidence that NSIs can be prevented. Despite differences in methodological approaches, the studies consistently showed significant effectiveness in reducing the risk of NSIs in healthcare settings. The training intervention reduced the rate of NSIs by 34% and the SEDs intervention reduced NSIs by 49%. When training was introduced along with SEDs, NSIs were reduced by 62%. We did not calculate an overall summary effect across all studies because of our a priori judgment that implementation of training alone, SEDs alone, and a combination of training and SEDs represented very different intervention strategies whose effects should not be averaged. A disadvantage of this decision was that each of the 3 subgroup analyses was based on a relatively small number of studies: 6, 5, and 8 for training, SEDs, and training plus SEDs interventions, respectively. In meta-analyses of this size, summary effect sizes should be interpreted with caution. We found evidence of heterogeneity of the effects of the training interventions, while SEDs and combined interventions had homogeneous summary effects.

The heterogeneity of the effect sizes among studies of training interventions may be due to the different content of training interventions, duration of interventions, and study populations. For example, some studies only included presentations on the use of standard precautions, while others added additional features such as the risk of infection from and the consequences of NSIs. In addition, some studies included all HCWs in a hospital, while other studies targeted specific occupational groups such as nurses. Many studies have reported that the risks of NSIs vary by occupation,[27–30] so it is reasonable to assume that the effectiveness of a training intervention may vary by occupation as well. However, we were unable to investigate this hypothesis because the number of studies reporting these specific data was very small.

Combining the 2 intervention approaches (training and SEDs) appears to be more effective than either intervention alone. This finding is in line with the conclusions of Ippolito et al,[31] who argued that successful NSI prevention needed to encompass many different interventions. Our finding that SEDs appear to be more effective than training was not surprising because SEDs reduce the exposure by modifying or isolating the hazard.[32,33] Training, in contrast, aims to reduce the risk by modifying the behavior of the subject (HCWs) without modifying the hazard from the devices.

In this meta-analysis, only 1 study that assessed the effectiveness of SED was conducted in a developing country.[19]

This is a concern because it suggests a lower level of concern for NSI prevention in developing countries, where the risk is, if anything, higher than that in the developed world.[34,35] The diffusion of SEDs in developing countries is subject to several practical impediments. First, SEDs are not widely available or used in healthcare setting because they are often considerably more expensive compared with the standard devices.[36] Furthermore, the design and manufacture of SEDs is more complex than for nonsafety devices. In addition, healthcare administrators may not view NSIs as a high priority, given other pressing healthcare needs.

The relative lack of research on NSI prevention in developing countries may also be partly attributed to barriers to epidemiologic research in these countries. Researchers may not be interested in this topic because they may have perceived that healthcare settings are a relatively safe place to work. Furthermore, a lack of training in healthcare surveillance research often discourages such studies. In addition, research funding may be more available for other communicable diseases with a wider at-risk population. Despite these concerns and challenges, some evidence has indicated that the introduction of SEDs in healthcare is not only health-protective but also cost-effective.[37,38]

Several challenges need to be considered in interpreting the study findings. First, the current study included a variety of study designs with different levels of accuracy and precision. As has been noted, only 1 randomized trial was included.[17] The possibility of biases in the individual studies that affected the summary effect estimates cannot be ruled out. Second, the populations included in the individual studies were diverse; some included only specific occupations such as nurses, and others included heterogeneous groups of different types of HCWs. Finally, most measures of association drawn from the individual studies were not adjusted for confounders, and the possibility remains that uncontrolled confounding biased the summary effects in some unknown way. Despite various drawbacks in the original studies, this meta-analysis did yield a quantitative summary of effects for 3 different NSI prevention interventions. All 3 interventions prevent NSIs, and the combination of training and SEDs is more effective that either intervention alone.

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