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Nursing Practices Towards Prevention of Medication Errors: A Systematic Review and Meta-Analysis

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Abstract: This meta-analysis aimed to systematically examine the articles about the practices of nurses to prevent medication errors in hospitals. This research was conducted using the meta-analysis method, one of the quantitative research methods. With the determined keywords, Google Scholar, Web of Science, Scopus, Science Direct, EKUAL, Google Academic EBSCOhost, MEDLINE, CINAHL, PUBMED, and ULAKBİM TIP electronic databases were scanned. Thirty-two full-text articles published in peer-reviewed journals between 2000-2020 were included in the study. The study's effect size and publication bias included in the meta-analysis were calculated using the CMA 3 (Comprehensive Meta-Analysis) program. The total sample number of the studies included in the analysis is 3894. According to the random-effects model, the overall effect size between medication errors and nursing practices to prevent medication errors was statistically significant, with a value of 1,949 (G.A; 1,463-2,519; $p < 0.05$). As a result of this meta-analysis, it was determined that continuing education, technology-based practices, and mixed methods (correct principles in drug administration, prevention of interruptions and divisions, policies and procedures) effectively prevent medication administration errors in the hospital.

Keywords: nurse; patient safety; prevention; medication errors.

1. Introduction

Medication errors are preventable event that contributes to morbidity, mortality, and increased healthcare costs. Are under the control of a healthcare professional and have a crucial role in promoting patient safety [1,2]. Medication errors; occurs with the administration of the wrong medication, administering the medication to the wrong patient, the wrong dose, the wrong administration route, the wrong medication form, and the wrong medication administration. In the study conducted by Drach-Zahavy, & Pud (2010), It was determined that the nurses did not follow the guidelines in defining the patient before giving the drug to the patient, the drugs were not prepared according to the control principle, and in cases where the drug was required during the administration, for example; It was found that measures such as controlling blood pressure were not taken, nurses did not inform the patient about the drug, and nurses for almost all drug administrations did not control possible side effects [3]. Medication errors lead to the prolonged hospital stay and increased treatment costs [4]. The report on the prevention of medication administration errors reported that the errors cause 1.5 million people to be injured [5]. If the process can be managed well, these errors can be reduced. In this direction, measures are taken, and nurses' practices to prevent medication errors by spending

40% of their time in drug management are critical [6]. This study aimed to systematically compile and meta-analysis the data obtained by reviewing the studies covering nursing practices to prevent medication errors. The results obtained from the study can guide clinical nurses on which methods and practices they can use to reduce medication errors and how they can be transferred to practice.

2. Materials and Methods

2.1. Type, place, and duration of the study.

This research was conducted using the meta-analysis method, one of the quantitative research methods. The study was conducted in the Health Management Department of the Institute of Health Sciences of a foundation university between February and March 2020. Since the research is a meta-analysis study, the literature review model was used. Since the literature search does not directly affect animals or humans, ethics committee approval was not obtained for the research.

2.2. Application steps of the study.

For the study's application steps, the articles included in the meta-analysis were classified based on PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyzes statement) and MOOSE (Meta-analysis of Observational Studies in Epidemiology) criteria. Articles that meet these criteria were determined and presented in Figure 1.

2.3. Detailed literature review - search strategy and selection criteria.

A preliminary literature search was conducted to identify keywords on the internet access network of a foundation university. With scanning medication administration errors in hospital and nurse, medication safety and nursing practice and patient, medication errors prevention and nurse and inpatient, drug administration errors and nurse and prevention hospital, reducing medication errors inpatient and Keyword combinations of nurse, strategies for reducing medication administration errors in the hospital setting and preventing medication administration errors in the hospital setting are used. Full-text articles published in peer-reviewed journals between 2000 and 2020 were scanned from the electronic databases of Google Scholar, Web of Science, Scopus, Science Direct, EKUAL, Google Academic EBSCOhost, MEDLINE, CINAHL, PUBMED, and ULAKBİM TIP. As a result of the literature review within the research scope, 2514 studies addressed nurses' practices to prevent medication errors. Thirty-two studies that comply with the criteria for inclusion in the research published between 2000 and 2020 were included in the meta-analysis. The included studies were evaluated by two separate evaluators using the quality assessment criteria suggested by Polit and Beck, and the kappa compliance rate was calculated in the SPSS 25 program. The study's protocol was recorded in the "PROSPERO" database, which provides systematic review and meta-analysis worldwide (I.D.= CRD42017054228). No study with a similar title was found. After the title and summary readings, the articles included in the full-text reading were determined. The article searches and screening diagram regarding the inclusion flow of the study's articles is presented in Figure 1.

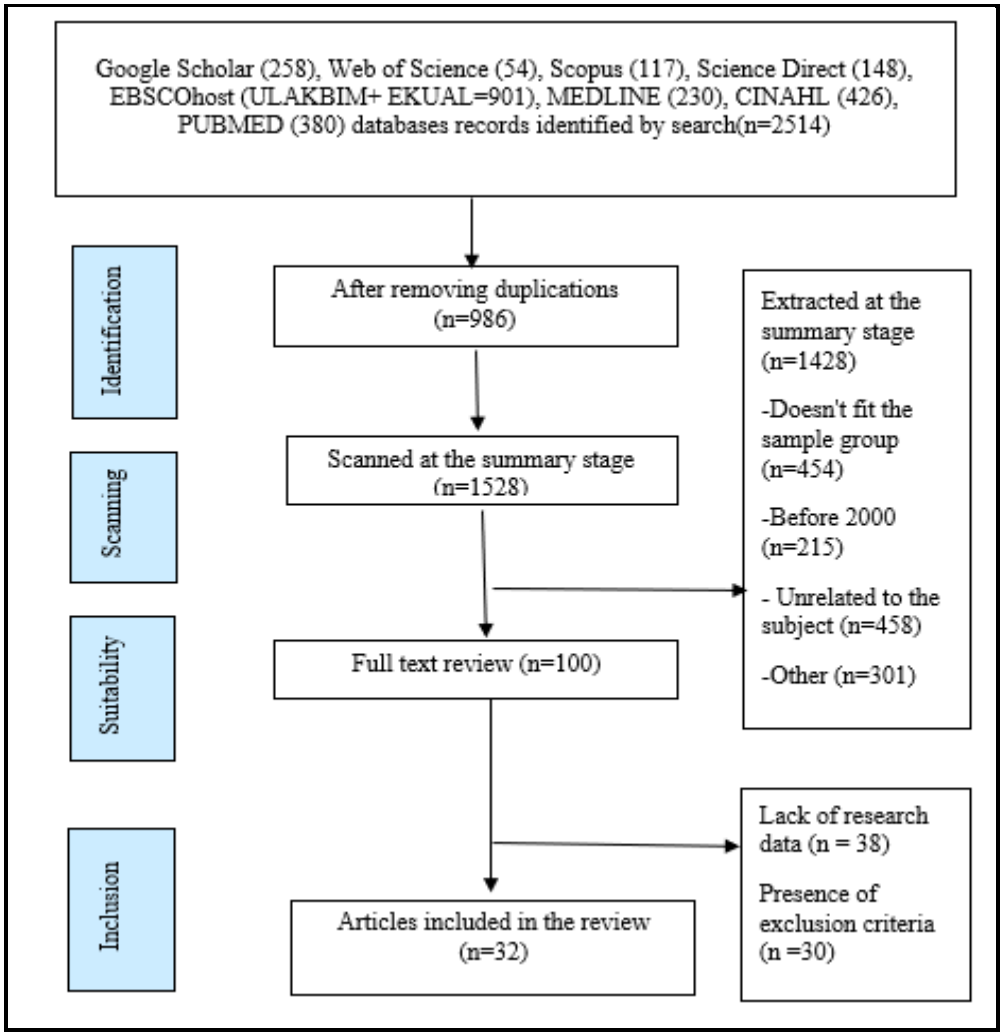

Figure 1. PRISMA 2 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement) Flowchart.

Searching Articles and Inclusion Criteria in Meta-Analysis: 1) Original articles (excluding qualitative studies, theses, books, reviews, letters, cases, and reports) 2) Randomized controlled studies, experimental and descriptive, full-text research articles written only in English and Turkish to prevent linguistic bias. 3) Articles accessible within the University and published in a National / International refereed journal on the subject 4) Full-text articles containing practices (excluding studies for non-nurse healthcare personnel) to prevent medication errors in hospitalized patients, Articles belonging to it were evaluated.

2.4. Methodological quality assessment according to the review, coding, and inclusion.

2.4.1. Criteria of articles.

Independent and detailed abstract and full-text readings of the articles were completed by two researchers/experts to prevent publication bias. The articles evaluated were coded according to their defining features. These defining features; The name and date of the study, purpose, sample size, preventive intervention, and essential findings to prevent mistakes (primary output) and quality evaluation scores. For the remaining 32 publications after the studies review, 12 of the research quality evaluation criteria proposed by Polit and Beck were used [7]. Each study was evaluated on all criteria and separately by the researchers, and if each item did not meet "1 point", a score of "0" was given. The scores the study can get according

to the criteria range from 0 to 12. In the study, articles belonging to all subgroups were examined independently by two researchers, and articles scoring seven or more in the quality evaluation were evaluated as quality. Four of the studies (n = 36) evaluated by independent evaluators were evaluated as "poor" and one as "moderate."

2.5. Analysis of data.

The frequency and percentage values of the combined sample numbers of 32 studies included in the meta-analysis were analyzed by evaluating the results of nurses' interventions to prevent medication administration errors in hospitals. "Comprehensive Meta-Analysis Academic / Non-profit Pricing (Version 3)" licensed software was used to analyze the data. The data of all articles meeting the inclusion criteria and decided to be included in the study were entered into the CMA software, and the heterogeneity of the articles was evaluated. Scattering in the funnel plot was examined in the first stage to determine whether there was a publication bias in the meta-analyzed studies. After the effect size values of each study included in the meta-analysis were calculated, a heterogeneity test was performed in the research. According to these test results, two models, fixed and random effects are used in the meta-analysis. Random effects model in group analysis with $p<0.05$ in heterogeneity test, effect sizes of all studies under the fixed-effects model in group analysis with $p >0.05$, study weights, 95% confidence intervals, and overall effect size were calculated. In evaluating the overall effect, the statistical significance limit was accepted as $p < 0.05$. Funnel Plot analysis was performed to test the publication bias, and the results of Classic Fail-Safe N and Tau coefficient calculations were used.

3. Results and Discussion

Descriptive (13), randomized controlled (2), experimental (1), quasi-experimental (3), prospective (4), retrospective (3), intervention study (1), cross-sectional (3), criticality analysis of the studies included in the meta-analysis (1) and sequential mixed method (1) were determined to be designed. It was determined that the samples varied in nurses' studies to prevent medication administration errors in the hospital. There are studies in which nurses are sampled (17), as well as studies in which observations (5), error records (4) systematic reporting data (1) are included in the sampling. In studies where nurses were included in the sample, it was observed that the sample size ranged from 12-691. It was determined that the size varied from 195-24337 in studies where the sample was error record and 1465-31080 in studies with observation. Five thousand two hundred fifty-four errors were detected in the studies where the critical analysis was performed.

In this study, kappa values ranged between 0.751-0.862 based on inter-rater reliability analysis articles. The overall fit ratio kappa value of 0.874 was found to be well-aligned [8].

3.1. Analytical findings effect sizes and heterogeneity.

In the study, a heterogeneity test was applied to determine the effect of nurses' interventions on preventing medication errors in hospitals. As a result of the heterogeneity test, the p-value was less than 0.05, and the Q (717,168) value was more significant than the value corresponding to the df value. As a result of the individual studies included in the analysis, it was determined that the studies examined according to the relationship between nurses' job satisfaction and organizational commitment were found to be heterogeneous. The I^2 statistic

value was calculated as 95,677. As a result of the calculations, the effect size distribution was evaluated according to the random-effects model (Table 1). As a result of the heterogeneity test, if the p-value is less than 0.05 or the Q value is greater than the value corresponding to the df value in the $\chi 2$ table, it is understood that the meta-analysis application is heterogeneous because of individual studies included in the analysis. Also, to determine the heterogeneity level, the I^2 statistic value was calculated as (95.567), stated reference points for $I^{2,}$ and expressed these values as low, medium, and high as 25%, 50%, and 75% [7].

Table 1. Heterogeneity test results for General.

Effect size and 95% Confidence Interval				
Model	**Number Studies**	**Point Estimate**	**Lower Estimate**	**Upper Limit**
Fixed	32	2.495	2.375	2.621
Random	32	1.949	1.463	2.597
Test Of Null (2-Tail)				
Model	**Z-Value**	**P-Value**		
Fixed	36.444	0.000		
Random	4.561	0.000		
Heterogeneity				
Model	**Q-Value**	**Df (Q)**	**P-Value**	**I-Squared**
Fixed	717.168	31	0.000	96.677
Random				
Tau-Squared				
Model	**Tau Squared**	**Standard Error**	**Variance**	**Tau**
Fixed	0.560	0.315	0.100	0.748
Random				

The meta-analysis results of 32 studies examining the effect of nurses' interventions to prevent medication administration errors in hospitals included in the study were shown with a forest plot. With the analysis performed according to the random-effects model, it was found that the overall effect size of the interventions made by nurses to prevent medication administration errors in hospitals was statistically significant, with a value of 1,949 (Confidence Interval, C.I; 1,463-2,597; $p< 0.05$). Table 2

Table 2. Forest graph of the effect of nurses' interventions to prevent drug administration errors in hospitals.

Study Name	**Statistics for each study**				
	Odds ratio	**Lower limit**	**Upper limit**	**Z-Value**	**p-Value**
[8]	2.848	1.832	4.425	4.653	0.000
[9]	1.179	0.632	2.201	0.517	0.605
[10]	2.347	1.217	4.526	2.545	0.011
[11]	1.474	0.992	2.189	1.919	0.055
[12]	2.558	1.929	3.391	6.525	0.000
[13]	4.211	2.866	6.188	7.321	0.000
[14]	2.583	1.878	3.551	5.840	0.000
[15]	7.684	4.833	12.219	8.618	0.000
[16]	0.090	0.061	0.133	-12.020	0.000
[17]	1.488	0.325	6.818	0.511	0.609
[18]	6.221	3.378	11.457	5.867	0.000
[19]	5.833	1.338	25.429	2.348	0.019
[20]	0.556	0.161	1.919	-0.929	0.353
[21]	5.277	3.470	8.026	7.776	0.000
[22]	1.645	0.431	6.276	0.729	0.466
[23]	1.853	0.980	3.502	1.899	0.058
[24]	1.437	1.220	1.693	4.337	0.000
[25]	1.179	0.632	2.201	0.517	0.605
[26]	1.883	1.297	2.733	3.327	0.001
[27]	3.250	2.487	4.246	8.637	0.000
[28]	0.174	0.051	0.596	-2.785	0.005
[29]	2.998	2.787	3.225	29.445	0.000
[30]	1.189	0.863	1.638	1.061	0.289
[31]	2.100	1.760	2.504	8.252	0.000

Study Name	Statistics for each study				
	Odds ratio	Lower limit	Upper limit	Z-Value	p-Value
[32]	1.752	0.229	13.423	0.540	0.589
[33]	5.982	2.718	13.164	4.444	0.000
[34]	1.095	0.475	2.527	0.213	0.831
[35]	0.599	0.441	0.812	3.294	0.001
[36]	6.129	5.000	7.512	17.454	0.000
[37]	0.681	0.421	1.100	-1.571	0.116
[38]	7.860	5.773	10.700	13.098	0.000
[39]	1.778	0.147	21.509	0.452	0.651
The general effect size	1.949	1.463	2.597	4.561	0.000

3.2. Analysis of publication Bias.

The results of the funnel scatter plot are also considered a visual summary of the meta-analysis data set and show the probability of publication bias, as shown in Figure 2. As shown in Figure 3, most of the 32 studies included are located very close to the combined effect size and the top. Publication bias above a certain level affects the average effect size to be calculated and makes it higher than it should be [40]. Kendall's tau b coefficient was also calculated, and the p-value was expected to be greater than 0.05 [41-43]. According to the values calculated in this statistic, publication bias was not observed in the studies included in the meta-analysis.

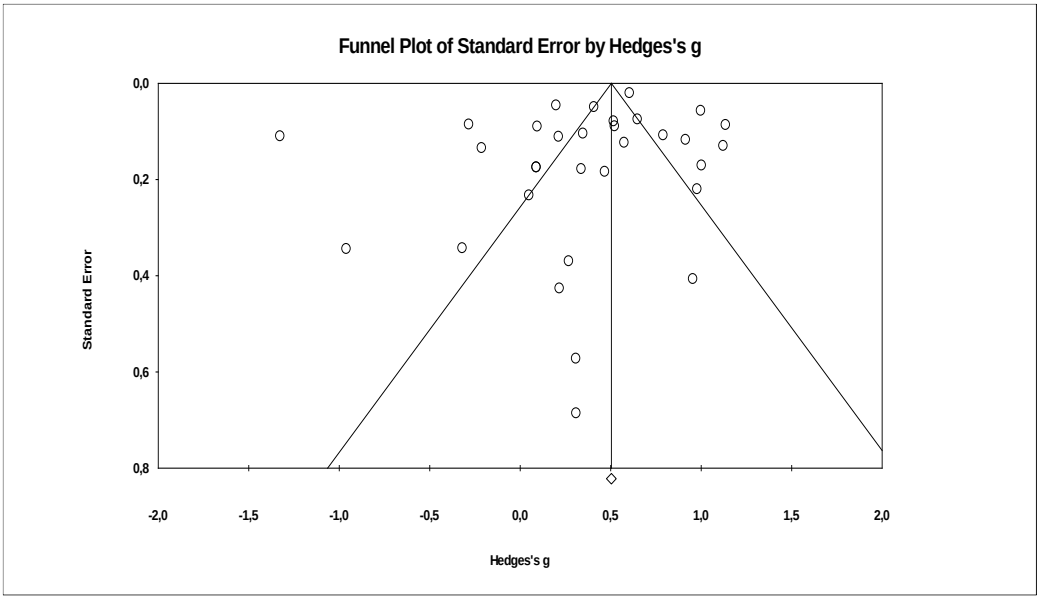

Figure 2. Funnel Scatterplot.

3.3. Discussion.

In this meta-analysis, which examines the studies conducted to prevent medication errors, high rates of medication errors were found. Eleven studies were found to show that education effectively reduces medication administration errors by nurses [8-21]. In these studies, the training given to nurses before and continuously for safe drug administration effectively reduces medication errors [16,17,20,21]. It has been observed in studies that educational practices are generally used to reduce personal errors. It is reported that healthcare professionals' training is critical in increasing safety in healthcare and reducing medication errors [8]. It is stated that insufficient drug knowledge increases nurses' risk of making medication errors [8,44]. Another study stated that nurse education is critical in reducing medication errors [45].

Also, seven studies show that the use of technological methods reduces medication administration errors [12,14,15,25,29,32,46]. Looking at the research results in general; Intelligent, unchangeable boundaries programmed infusion pumps in pharmaceutical applications BCMA (Barcode medication administration system) [12-15,25,29,32,38,46]. The use of color code labeling systems and electronic drug record systems for multiple infusions has been determined to be effective in reducing medication errors [25,29,32,38]. Technology is one of the popular approaches adopted in the prevention/reduction of medication errors [12-15,25,29,32,38,47,48]. Barcode technology reduces errors caused by patient identity verification during drug administration [49,50]. A color labeling system is also essential in reducing errors caused by mixing similarly named drugs and similar drug packaging [49-51]. Electronic drug record systems are effective in reducing medication errors [29,32]. This system is thought to reduce errors caused by illegible or poorly written physician requests [52,53]. In parallel with the study results, it is stated that nurses' computer-aided order entry and electronic drug registration systems are essential strategies for preventing errors [6-12-47]. There are ten studies in which more than one method and application are used to ensure drug safety [4-9,22,23,26,27,52,53].

When the results of these studies are examined in general; Compliance with five correct principles in drug administration physical change in the drug preparation room, hanging a warning sign in the treatment room, preparation of drug administration guidelines, deficiency of information, and determining the causes of error in memory [26,52]. Providing training, drug classification method, and a supportive application environment, increasing the number of nurses, and providing the sterile cockpit principle in intensive drug applications have been stated to reduce errors [22,23,26,30]. All these factors cause medication errors [54]. It is seen that interventions aimed at eliminating these causes of error were made in the studies examined. The critical relationship between interruptions in drug administration and drug error rate supports research findings [51]. In parallel with the research results, in the study of Alsulami et al. (2012), it was stated that the double control method in drug applications reduces the risk of medication errors [47]. Some articles stated that dual control with two nurses while preparing and administering medication is essential in reducing medication errors [55,56]. In a study in which more than one method and application were included in the research, it was found that internal and external guidelines and interventions used in the JCI accreditation process reduced medication errors (organization, education, process improvement, and information technology) [30]. In parallel with the study results, it was determined that the development of standards and procedures could prevent medication errors to a great extent [6].

4. Conclusions

Pharmaceutical applications are very complex procedures. Nurses, primarily responsible for drug administration in hospitals, play a crucial role in preventing errors. As a result of this systematic review, it is seen that the rate of errors is high. Knowing the mistakes made, taking necessary precautions, and preventing possible mistakes are also considered essential. In the studies conducted, it is seen that the errors are not only individual but also system and organization.

For this reason, multiple approaches that consider the individual, system, and organization should be used to prevent errors. In general, education, technology, and different methods are used together to prevent mistakes. These methods: Continuous education (online, web-based, simulation training), technology-based applications (barcode-assisted drug

application, computer-assisted order entry), and mixed methods (correct principles in drug applications, prevention of interruptions and divisions, policies, and procedures) were determined to be effective. However, it has been observed that the strategies to prevent medication administration errors differ according to the facilities and needs of the institutions. The results obtained from the study may guide clinical nurses on what methods and practices they can use in reducing medication administration errors and how they can be transferred to practice. Prevention of application errors is essential for hospital administrators as medication errors threaten patient safety, prolong hospital stay, and increase health expenditures accordingly. The study will also be useful for researchers as it reveals the missing areas preventing medication administration errors in the hospital. It is essential for nurses working in management, practice, research, and education to benefit from research results to reduce medication administration errors, reduce errors, and ensure and maintain patient and employee safety. It has been observed that it is essential to provide continuous training with different training methods, benefit from information technologies, make institutional arrangements, and ensure and maintain internal and inter-institutional cooperation regarding reducing medication errors. It may be suggested that research should be done multi-center, using different methods, emphasizing experimental and randomized controlled studies.

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Conflicts of Interest

The authors declare no conflict of interest.

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