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Improvement of drug dose calculation by classroom teaching or e-learning: A randomized controlled trial in nurses

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ABSTRACT

Introduction: Insufficient skills in drug dose calculations increase the risk for medication errors. Even experienced nurses struggle. Learning flexibility and cost considerations make e-learning interesting as an alternative to classroom teaching. This study compared the learning outcome and risk of error after a course in drug dose calculation for nurses with the two methods.

Methods: In a randomized, controlled, open study, nurses from hospitals and primary health care were randomized to either e-learning or classroom teaching. Before and after a two-days' course, the nurses underwent a multiple-choice test in drug dose calculations: fourteen tasks with four alternative answers (score 0-14), and a statement regarding certainty of each answer (score 0-3). High risk of error was being certain that incorrect answer was correct. The results are given as mean(SD).

Results: Sixteen men and 167 women participated in the study. Age were 42.0(9.5) and working experience 12.3(9.5) years. Total scores after e-learning and classroom teaching were 11.6(2.0) and 11.9(2.0) respectively (p=0.18,ns), and improvement were 0.5(1.6) and 0.9(2.2) respectively (p=0.07,ns). Classroom was significantly superior to e-learning among participants with pre-test score below 9. Factors in favour of e-learning was less time consumption, and higher value for working situation. There was no difference in risk of error between the groups after the course (p=0.77).

Conclusions: The study showed no differences in learning outcome or risk of error between e-learning and classroom teaching in drug dose calculation. The overall learning outcome was small. Weak pre-course knowledge was associated with better outcome after classroom teaching.

ARTICLE SUMMARY

Strengths and limitations of this study

- Medication errors are often considered to be due to stressful working situations, lapses in attention, or disturbances. This study demonstrates that more basic and continuing training in drug dose calculation is needed to prevent errors.
- The method includes a certainty evaluation of each drug dose calculation, which contributes to identify areas with high risk of error.
- Choosing between classroom teaching and e-learning do not solve the underlying problem with poor numeracy.
- The controlled test conditions may be regarded as a limitation. Although the testing of drug dose calculation is perceived as stressful in itself, it is not equal to the time pressure or disturbances in a working situation, when errors occur.

INTRODUCTION

From international reviews and reports of adverse drug events, incorrect doses account for up to 1/3rd of the events.(1-3) Most health professionals find drug dose calculations difficult. The majority of medical students are unable to calculate the mass of a drug in solution correctly, and around half the doctors are unable to convert drug doses correctly from a percentage concentration or dilution to mass concentration.(4, 5) Both in hospitals and primary health care the nurses carry out the practical drug management after the physicians' prescriptions. In Norway, a faultless test in drug dose calculation during nursing education is required to become a registered nurse.(6) Both nursing students and experienced nurses have problems with drug dose calculations, and nursing students early in the program show limited basic skills in arithmetic.(7-10) We have shown a high risk of error in conversion of units in 10 % of registered nurses in an earlier study.(11)

E-learning was introduced with the Internet in the early 1990s, and has been increasingly used in the medical and health care educations. E-learning is independent of time and place, and the training is easier to organize in the health services than classroom teaching, and to a lower cost. A meta-analysis from 2009 summarized more than 200 studies in health professions education, and concluded that e-learning is associated with large positive effects compared with no intervention, but compared to other interventions the effects are generally small.(12) There is lack of drug dose calculation studies where different didactic methods are compared.

The objective of this study was to compare the learning outcome, certainty and risk of error in drug dose calculations after courses with either self-directed e-learning or conventional classroom teaching. Further aims were to study factors associated with the learning outcome and risk of error.

METHODS

A randomized, controlled, open study with parallel group design.

Participants

Registered nurses working in two hospitals and three municipalities in Eastern Norway were recruited to participate in the study. Inclusion criteria were nurses with at least one year of work experience in 50 % part time job or more. Excluded were nurses working in outpatient clinics, those who did not administer drugs, and any who did not master Norwegian language sufficiently. The study was performed from September 2007 to April 2009.

Interventions

At inclusion, all participants completed a form with relevant background characteristics, and nine statements from the General Health Questionnaire (GHQ 30).(13) Quality of Life tools are often used to explore psychological well-being. The GHQ 30 contains the dimensions sense of coping and self esteem/well-being, and was used to evaluate to what extent the nurses' sense of coping affected their calculation skills. The nurses performed a multiple-choice (MCQ) test in drug dose calculation. The questions were standard calculation tasks for bachelor students in nursing at university colleges. The test was taken either on paper or on an Internet web site. The time available for the test was 1 hour, and the participants were allowed to use a calculator.

After the test, the nurses were randomized to one of two two-day courses in drug dose calculation. One group was assigned to a self directed, interactive internet based e-learning course developed at a Norwegian university college. The other was assigned to conventional classroom course with lectures, exercises and text book, used at the same college.(14) Two to four weeks after the course, the nurses were re-tested in drug dose calculation with a similar MCQ test as the pre-test.

Sample size

Studies testing drug dose calculation in nurses have shown a mean score of 75 % (SD 15%) (15-17). In a study with 14 questions, this is equivalent to a score of 10.5 (SD 2.1). To detect difference of one correct answer between the two didactic methods with the strength of 0.8 and alfa<0.05, it was necessary to include 74 participants in each group. Because of likely dropouts, the aim was to randomize 180 participating nurses.

Randomization

At inclusion, each nurse was stratified according to five workplaces: internal medicine, surgery or psychiatric wards in hospitals, and nursing home or ambulatory care in primary health care. Immediately after submission of the pre-test, the participants were randomized to one of the two didactic methods, by predefined computer generated lists for each stratum.

DATA COLLECTION

Participant characteristics

The following background characteristics were recorded: age; gender; childhood and education as a nurse in or outside of Norway; length of work experience as a nurse in at least a 50 % part-time job; job size past 12 months; present workplace in a specific hospital department (surgery, internal medicine or psychiatry) or primary health care (nursing home or ambulatory care); and frequency of drug dose calculation tasks at work, score 0-3: 0=less than monthly, 1=monthly, 2= weekly, 3=every working day. Further educational background was recorded (yes/no): mathematics beyond the first mandatory year at upper secondary school; other education prior to nursing; postgraduate specialization; and courses in drug dose calculation during the latest three years. The participants registered motivation for the courses in drug dose calculation, rated as 1=very unmotivated, 2=relatively unmotivated, 3=relatively motivated, 4= very motivated

In addition, the participants were asked to consider statements from GHQ30, in the context of performing medication tasks: five regarding coping (finding life a struggle; being able to enjoy normal activities; feeling reasonably happy; getting scared or panicky for no good reason; and being capable of making decisions), and four regarding self esteem/well-being (overall doing things well; satisfied with the way they have carried out their task; managing to keep busy and occupied; and managing as well as most people in the same situation). The ratings of these statements were 0-3: 0=more/better than usual, 1=as usual, 2=less/worse than usual, and 3=much less/worse than usual; "as usual" was defined as the normal state.

Outcomes

Drug dose calculation test and certainty in the calculations

A drug dose calculation test was performed before and after the course: 14 multiple choice questions with four alternative answers. The topics were as follows (number of questions in brackets): conversion of units (7), formulas for calculation of dose, quantity or strength (4), infusions (2), and dilutions (1). For each question, the participants indicated a self-estimated certainty, graded from 0-3: 0=very uncertain, and would search for help, 1=relatively uncertain, and would probably search for help, 2=relatively certain, and would probably not search for help, and 3=very certain, and would not search for help.

Risk of error

Risk of error was estimated by combining knowledge and certainty for each question rated on a scale from 1 to 3, devised for the study. Correct answer combined with relatively or high certainty was regarded as a low risk of error (score=1), any answer combined with relatively or very low certainty was regarded as a moderate risk of error (score=2), and incorrect answer combined with relatively or high certainty was regarded as a high risk of error (score=3).

Course evaluation

After the course, the nurses recorded the time spent for self study (0-3 hours, 3-6, 6-9, 9-12, 12-15, more than 15 hours); assessment of the level of difficulty of the course related to their own prior knowledge (1=very difficult, 2=relatively difficult, 3=relatively easy, 4 =very easy); and course satisfaction (1=very unsatisfied, 2=relatively unsatisfied, 3=relatively satisfied, 4=very satisfied). An evaluation of the usefulness of the specific course in drug dose calculation in daily work as a nurse was rated from 1=very small, 2=relatively small, 3=relatively large to 4=very large.

Ethical considerations

The Norwegian Data Inspectorate, represented by Privacy Ombudsman for Research, approved the study. Further ethics committee approval was not applicable. All participants gave written informed consent. The tests were performed de-identified. A list connecting the study participant number to the names was kept until after the re-test, in case any of the participants had forgotten their number. To protect the participants from any consequences because of the test, the data were made anonymous before the analysis.

Even if the study might uncover that individuals showed a high risk of medication errors due to lacking calculation skills, it was considered ethically justifiable not to be able to expose their identity to their employer.

Data analysis

The analysis was performed with intention-to-treat analyses. In addition, a per protocol analysis was performed for the main results. Depending on data distribution, comparisons between groups were analyzed with Chi-square or Fishers exact test, t-test or Mann-Whitney U-test, ANOVA, Friedman, and Pearson or Spearman tests for correlations. All variables possibly associated with learning outcome and change in risk of error were entered in standard multiple regression analyses to identify independent predictors (18). Two-tailed significance tests were used, and a p-value < 0.05 was considered statistically significant.

The protocol contained instructions for handling of missing data. Unanswered questions were scored as “incorrect answer,” and unanswered certainty score as “very uncertain”. For participants who did not take the test after course, the result from the pre-test (“last observation”) was carried forward. The analysis was performed with SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). All results are given as mean and (SD) if not otherwise indicated.

RESULTS

In total, 212 registered nurses were included in the study, and 183 were eligible for randomization. **Figure 1** shows the flow of participants throughout the study, and **Table 1** summarizes the participant characteristics and the pre-test results. The two groups were well balanced with respect to baseline characteristics. Of the 183 nurses, 79 (43%) were recruited from hospitals (48 from surgery departments, including intensive care units; 23 from internal medicine wards; 8 from psychiatric wards), and 104 (57 %) from primary health care (52 from nursing homes and 52 from ambulatory health care). Nearly half of the nurses (48 %) performed drug dose calculations weekly or more often.

There was a tendency for more dropouts in the e-learning group; 18.4 % vs. 9.9 % (p=0.10). The dropouts did not differ from those who completed the study regarding workplace: 12 from hospitals and 14 from primary health care (p=0.74), or pre-test result: score 10.5 vs. 11.1, 95% CI for difference -1.5:+0.2, (p=0.13).

Table 1 Participants' characteristics and pre-test results

	E-learning (n=92)	Classroom (n=91)	P-value
Participants` characteristics			
Age (years)	41.6 (8.8)	42.4 (10.1)	0.57
Gender (men)	8 (8.7 %)	8 (8.8 %)	0.98
Childhood outside Norway	7 (7.6 %)	7 (7.7 %)	0.98
Nurse education outside Norway	5 (5.4 %)	4 (4.4 %)	0.75
Work experience as nurse (years)	12.8 (9.6)	11.7 (9.3)	0.44
Job size latest 12 months (full time=1)	0.84 (0.18)	0.88 (0.15)	0.13
Working in hospital	42 (45.7 %)	37 (40.7 %)	0.50
Frequency of drug dose calculation tasks at work (0-3) [2)]	1.5 (1.1)	1.3 (1.1)	0.28
Mathematics beyond 1st year high-school/USS[1)]	38 (41.3 %)	38 (41.8 %)	0.95
Other education before becoming a nurse	37 (40.2 %)	41 (45.1 %)	0.51
Postgraduate specialization	31 (33.7 %)	26 (28.6 %)	0.45
Course in drug dose calculation latest 3 years	9 (9.8 %)	13 (14.3 %)	0.35
Motivation for course in drug dose calculation (1-4)	3.3 (0.5)	3.2 (0.5)	0.12

Pre-test results			
Sense of coping (0-3)[3)]	0.79 (0.25)	0.81 (0.31)	0.60
Sense of self esteem/well-being (0-3) [3)]	1.01 (0.18)	1.03 (0.21)	0.45
Knowledge (score 0-14)	11.1 (1.7)	11.0 (2.3)	0.80
Certainty (score 0-3)	2.1 (0.6)	1.9 (0.6)	0.35
Risk of error (score 1-3)	1.4 (0.2)	1.5 (0.3)	0.27

The results are given as mean (standard deviation in brackets), or number of participants (proportion in brackets).
1) Upper secondary school
2) Scale: 0= less than monthly, 1= monthly, 2= weekly, 3= every working day.
3) Scale: 0= more/better than usual, 1= as usual, 2=less/worse than usual, 3= much less/worse than usual.

Knowledge, learning outcome and risk of error

The test results before and after course are shown in **figure 2**, and the upper part of **table 2** gives the main results after e-learning and classroom teaching. No significant difference between the two didactic methods were detected for overall test score, certainty or risk of error. The overall knowledge score improved from 11.1 (2.0) to 11.8 (2.0), ($p<0.001$). Before and after the course, 20 (10.9 %) and 37 (20.2 %) participants, respectively, completed a faultless test. The overall risk of error decreased after course; from 1.5 (0.3) to 1.4 (0.3), ($p<0.001$), but 41 nurses (22 %) showed an increased risk; 20 from the e-learning group and 21 from the classroom group. This proportion is within the limits of what could appear by coincidence from a normal distribution (24 %), and the mean learning outcome of 0,7 (0.2).

Table 2 Main results after course in drug dose calculations

	Results after course			Changes from pre-test		
	E-learning	Classroom	p-value	E-learning	Classroom	P-value
All participants	n=92	n=91		n=92	n=91	
Test score (score 0-14)	11.6 (2.0)	11.9 (2.0)	0.18	0.5 (1.6)	0.9 (2.2)	0.07
- Conversion of Units (0-7)	5.5 (1.3)	6.0 (1.2)	0.005	0.3 (1.2)	0.9 (1.5)	0.04
- Dose-quantity-strength (0-4)	3.6 (0.6)	3.4 (0.8)	0.12	0.2 (0.7)	0.03 (0.7)	0.86
- Infusions (0-2)	1.7 (0.5)	1.7 (0.5)	0.64	0.01 (0.4)	0.02 (0.7)	0.21
- Dilutions (0-1)	0.8 (0.4)	0.8 (0.4)	0.98	0.05 (0.4)	0.01 (0.5)	0.90
Certainty (score 0-3)	2.3 (0.5)	2.2 (0.6)	0.24	0.2 (0.6)	0.3 (0.6)	0.27
Risk of error (score 1-3)	1.4 (0.3)	1.4 (0.3)	0.77	-0.1 (0.2)	-0.1 (0.3)	0.29
Participants with pre-test score ≥ 9 [1)]	n=85	n=76		n=85	n=76	

Test score (score 0-14)	11.9 (1.8)	12.2 (1.9)	0.29	0.5 (1.6)	0.4 (1.8)	0.74
Certainty (score 0-3)	2.3 (0.5)	2.2 (0.7)	0.18	0.2 (0.6)	0.3 (0.7)	0.73
Risk of error (score 1-3)	1.3 (0.3)	1.4 (0.3)	0.61	-0.1 (0.2)	-0.1 (0.3)	0.92
pre-test score < 9 [1)]	n=7	n=15		n=7	n=15	
Test score (score 0-14)	8.4 (0.3)	10.7 (2.2)	0.01	0.7 (1.3)	3.6 (1.8)	0.001
Certainty (score 0-3)	1.9 (0.5)	2.0 (0.5)	0.74	0.2 (0.7)	0.4 (0.4)	0.40
Risk of error (score 1-3)	1,7 (0.2)	1.5 (0.2)	0.03	-0.1 (0.2)	-0.3 (0.3)	0.04

Results are given as mean (SD)
[1)] Auxiliary sub group analysis

An analysis of the main results from the 141 participants who completed the study according to protocol, generally showed the same as the intention to treat analysis, with no difference between the two didactic methods. The overall knowledge score improved from 11.1 (2.0) to 12.0 (2.0) (p<0.001).

Table 3 gives the results as proportion of correct answers and the proportion of answers with a high risk of error within each calculation topic before and after course. The test results in each topic for the two didactic methods showed that the classroom group scored significantly better after course in conversion of units: 86 % correct answers vs. 78 %, p<0.001, with no difference in the other topics. Overall, there were significant differences between the four topics in knowledge and risk of error both before and after course, p<0.001. Sense of coping or self esteem/well-being was not affected by the course for neither of the groups, data not shown.

Table 3 Knowledge and high risk of error within each calculation topic before and after course

	Proportion of correct answers (n=183)			Proportion of answers with a high risk of error (score=3) (n=183)		
Topic (number of questions)	Before course	After course	P-value	Before course	After course	P-value
Conversion of Units (7)	73.9(20.2)	81.8(18.9)	<0.001	10.6(14.6)	10.6(14.7)	0.93
Dose-quantity-strength(4)	84.7(16.9)	87.2(17.2)	0.06	3.0 (8.2)	5.0 (11.1)	0.02
Infusions (2)	83.5(27.8)	84.4(26.0)	0.70	4.0(16.1)	4.0 (15.6)	0.87
Dilutions (1)	81.4(39.0)	84.7(36.1)	0.32	6.0(23.8)	5.0 (22.8)	0.80
In total (14)	78.9(14.3)	83.9(14.5)	<0.001	7.1 (9.6)	7.7 (9.6)	0.51

Results are given as mean (SD).

Factors significantly associated with good learning outcome and reduction in the risk of error after course is given in **Table 4.** Among these factors, the randomization to classroom teaching was significantly better in learning outcome, adjusted for other variables. Both low pre-test knowledge and certainty score were associated with reduced risk of error after course, as were being a man and working in hospital. Self-evaluations of coping and self esteem/well-being were neither associated with learning outcome nor risk of error. The total R^2 change for the variables significantly associated with good learning outcome and risk of error were 0.28 and 0.18, respectively.

Table 4 Factors significantly associated with learning outcome and reduction in risk of error after course in drug dose calculation

	Learning outcome		Reduction in risk of error	
	Beta	***P-value***	***Beta***	***P-value***
Sex (man)			0.20	0.006
Working in hospital	0.21	0.02	0.26	0.005
Pre-test knowledge score	-0.61	<0.001	-0.29	0.001
Pre-test certainty score			-0.25	0.003
Randomization – classroom	0.16	0.02		
Motivation for course	0.17	0.02		

Multivariable regression analysis with all participant characteristics included as possible factors (n=183).

Course evaluation

Nearly all (97.5 %) of the participants stated a need for training courses in drug dose calculation. The evaluation after the course showed no difference between the didactic methods in expressed degree of difficulty or course satisfaction, data not shown. Time used for self-studying was median 3-6 hours for the e-learning and 0-3 hours for the classroom group (classroom session not included), $p<0.001$. The time used was not associated with the learning outcome. Adjusted for time for learning the randomization was no longer significantly associated with learning outcome, data not shown. The specific value of the course for working situation was scored 3.1 (0.7) in the e-learning group and 2.7 (0.7) in the classroom group ($p<0.001$).

Auxiliary analyses

A posthoc analysis for sub groups with pre-test knowledge score $\geq$ 9 and <9 is given in the lower part of **table 2**. For the participants with low pre-score, classroom teaching gave significantly better learning outcome and reduced risk of error after course. The overall knowledge score improved in the high score group from 11.6 (1.4) to 12.0 (1.9) and in the low score group from 7.2 (1.0) to 9.9 (2.3), and the difference in learning outcome was highly significant ($p<0.001$).

DISCUSSION

Drug dose calculation skills

The study was not able to demonstrate an overall difference in learning outcome between the two didactic methods, neither of statistical nor clinical importance. Both methods resulted in improvement of drug dose calculations after course, although the learning outcome was smaller than what was defined as clinically relevant. Adjusted for other contributing factors for learning outcome in the multivariable analysis, the classroom method was statistically superior to e-learning, and so was the case for a sub group with low pre-test result. This finding from the post hoc analysis was probably the only outcome that could have a meaningful practical implication for choice of learning strategy, if reproduced in new studies. These results were in accordance with a meta-analysis of 201 trials comparing e-learning with other methods.(19) The review summarized that any educational action gives positive outcome, regardless of method. E-learning works compared to no intervention, but tested against conventional methods it is difficult to detect any differences.

Drug dose calculations are not advanced in a mathematical sense. The basic arithmetic functions of addition, subtraction, multiplication or division are needed to decide decimals and fractions. What seems to be challenging is to conceptually understand the difference in information from the concentration denomination: percent or mass per unit volume, or the ability to set up the right calculation for the relationship between dose or mass, volume or amount and concentration or strength. A standard labelling to mass per unit volume has been strongly recommended.(20, 21)

The fact that only one out of ten nurses performed a faultless pre-test was not surprising, from what is previously shown. In a study by McMullan only 5 % of the nurses achieved 80 % correct calculations.(22) Although statistically significant, the limited overall learning outcome after the courses was somewhat disappointing, with only two out of ten with faultless tests. It seemed that the incorrect calculations were more frequent in conversion of units, the least complex task in mathematical sense. The conversion of units improved the most after course, while the learning outcome in the arithmetic tasks of infusions and dilutions were unchanged. This has also been observed by other investigators, and support the view that the challenges in drug dose calculation is more likely due to poor conceptual understanding.(10)

Risk of error

The study was not able to demonstrate any difference in the risk of error between the e-learning and classroom groups, neither before nor after course. Asking for certainty in each calculation made it possible for the nurses to express whether they normally would have consulted others or not when doing the calculation. Being certain that an incorrect answer was correct, was regarded as an adequate estimate for high risk of error, and to our knowledge, such method for estimating a risk of error from a test situation is not described by others. Due to the low learning outcome, one could fear that increased certainty would lead to increased risk of error. Therefore, it was satisfying that the overall risk of error declined after course with both methods. Although a proportion of 22 % with increased risk of error after taking the course seemed alarming, it was within the limit of what could occur by chance, due to the small learning outcome. However, one may speculate if an increased risk may be due to some participants felt safer, but not obtained increased knowledge. This might have implications for the need of follow-up after courses.

The factors that were associated with reduced risk of error after the calculation course could indicate who might benefit from training like this: being a man; working in hospital; low pre-test score; and low pre-test certainty score. This supports the finding in the auxiliary analysis; that nurses with weak drug dose calculation skills benefit most from taking courses. Nevertheless, the risk of error demonstrated in the study did not necessarily reflect the real risk of adverse event affecting patients, as the test situation cannot measure how often miscalculations were performed or how serious the clinical implications might be for any patient. Such studies still need to be done.

Importance for practice

The fact that 48 % of the participants in the study performed drug dose calculations at least weekly was more than anticipated. It has been a common perception that the need for most nurses to calculate drug doses is small in today's clinical practice. The reported extent of calculations underscores the importance of good skills in this field.

When the need for continuous improvement and maintenance of skills are identified, the time and resources available will be decisive for the possibility to implement further training activities. E-learning is more often a preferred choice in health services institutions, as it is both flexible and cost effective. Our study confirms less time consumption by e-learning, but this method also had more dropouts and lesser learning outcome for those with low skills. In a review article commenting upon the results of a meta-analysis of e-learning and conventional instruction methods, Cook claims that rather than more comparative studies, further research should focus on under which conditions ("how and when") e-learning is a preferable method.(12)

An implication of the findings can be to let nurses regularly perform an e-learning course followed by a screening test to uncover the weak calculation topics. Those who need further training should be offered a more tailored follow-up. Others have also documented that a combination of different learning and teaching strategies do result in better retention of drug calculation skills compared to lectures alone.(23)

Interestingly, the e-learning group stated a higher specific value of the course for working situation, although the course content was similar in both methods. This may be explained by the flexibility of the e-learning course, allowing the participants to concentrate on the items that were considered difficult and relevant for their work, while the classroom group had to follow through the whole programme. Nearly all the nurses realized themselves that they need more training in drug dose calculations, and an important factor was that motivation for course was associated with good learning outcome in the study. This indicates that the professional leadership in health institutions should facilitate and encourage the nurses to improve their skills further in drug dose calculations.

I addition to regularly training in calculations, written procedures for specific dilutions and infusions used in the wards would be of importance as a quality insurance for improved patient safety. This must be a part of the management responsibility.

Study limitations

The participants in this study were recruited through the management line, and the study population represents a limited part of the total nurse population. We assume that nurses with low calculation skills to a lesser degree would volunteer for such a study, and hence presume that the calculation skills in clinical practice would be lower than shown in this study. External validity might be an issue in studies with voluntary participation, and extrapolation of the findings of the study to all registered nurses should be performed with caution.

Some may question the quality of the course content and duration or teaching conditions of the courses, especially since the learning outcome of the courses were not convincing. However, the main aim for the study was to compare the two didactic methods. And, to ensure a fair comparison and similar content of the courses, the subject teacher who was a part of the group that developed the e-learning course, also was responsible for the classroom lectures. Since the teacher had an interest in both didactic methods, the probability for her to affect the course arrangements in favour of one of them was regarded as small. The questionnaire used was the same as nursing students were tested by, and the calculation tasks were considered to be in accordance with the tasks that were done in the nursing practice. The additional questions devised for the study; the certainty score and the risk of error estimations, were not validated tools, and could be regarded as a methodological limitation.

Another limitation could be the controlled test conditions, without time pressure and interruptions that are often the case in a stressful work situation, which tend towards better results than in reality. On the other hand, the calculation test situation itself may be stressful for the nurses, since many have struggled to pass a similar test during their studies.

Selecting two dimensions from the GHQ30 questionnaire may also be a methodological limitation. Although no correlation between the outcomes and coping or well-being/self esteem were detected, the usage of only parts of the tool excluded the possibility of detecting an association between physiological well-being in general and drug dose calculation skills.

CONCLUSION

The study was not able to demonstrate any differences between e-learning and classroom teaching in drug dose calculation, with respect to learning outcome, certainty or risk of error. The overall learning outcome was without practical significance, and conversion of units was the only topic that was significantly improved after course. An independent factor in favour of classroom teaching was weak pre-test knowledge, while factors suggesting use of e-learning could be the need for training in relevant work specific tasks and time effective repetition.

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Competing interests

BOS, IJ and PGF: None

GKD was part of the group who developed the e-learning programme used in the study, and the course was made commercially available from autumn 2009.

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Data sharing

The full protocol, the questionnaires and extra data are available by e-mailing the corresponding author: bjorg.simonsen@sykehuset-innlandet.no.

The questionnaire is also avaliable in English translation as an appendix to an earlier publication: Simonsen et al. BMC Health Services Research 2011, 11:175

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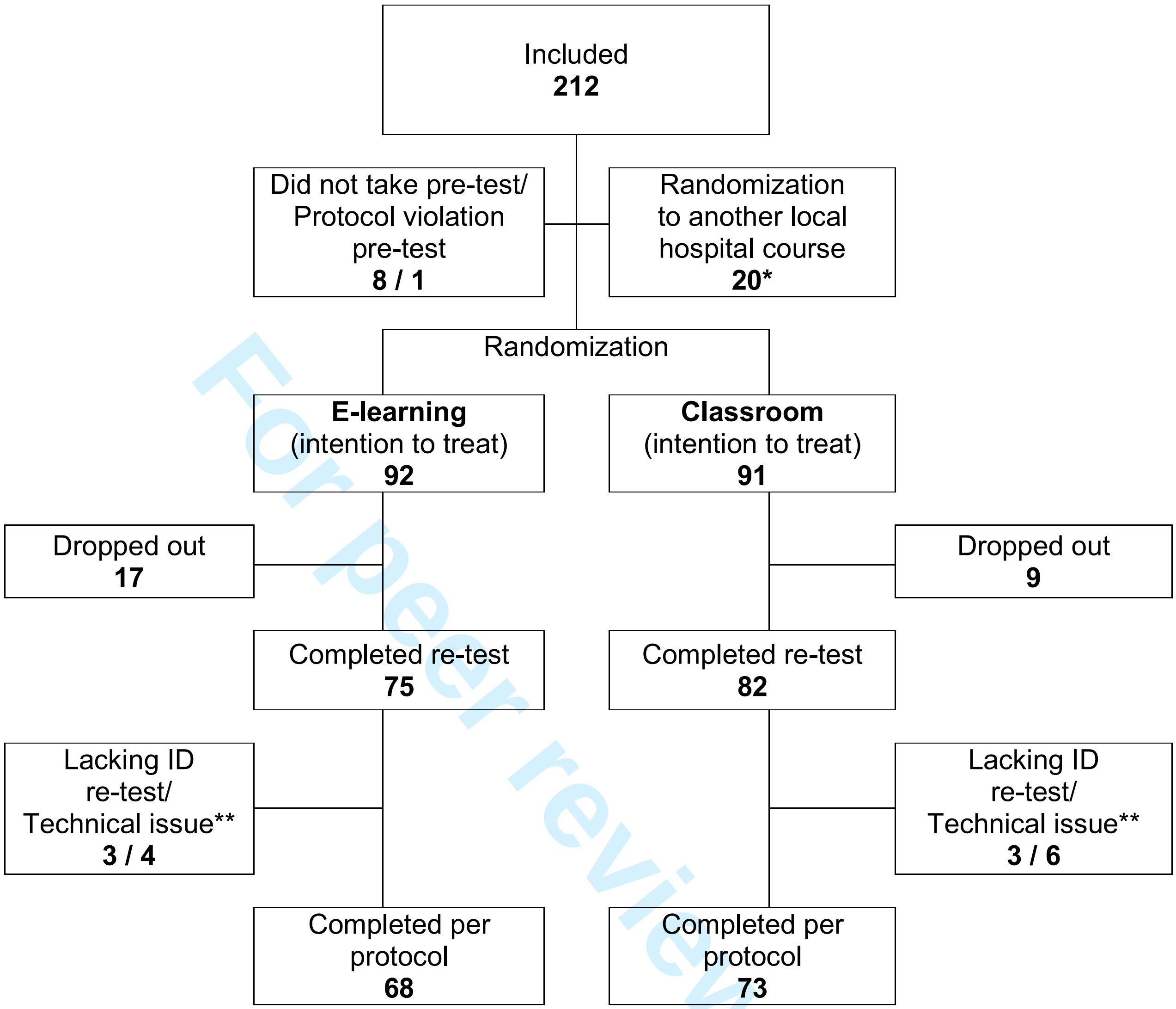
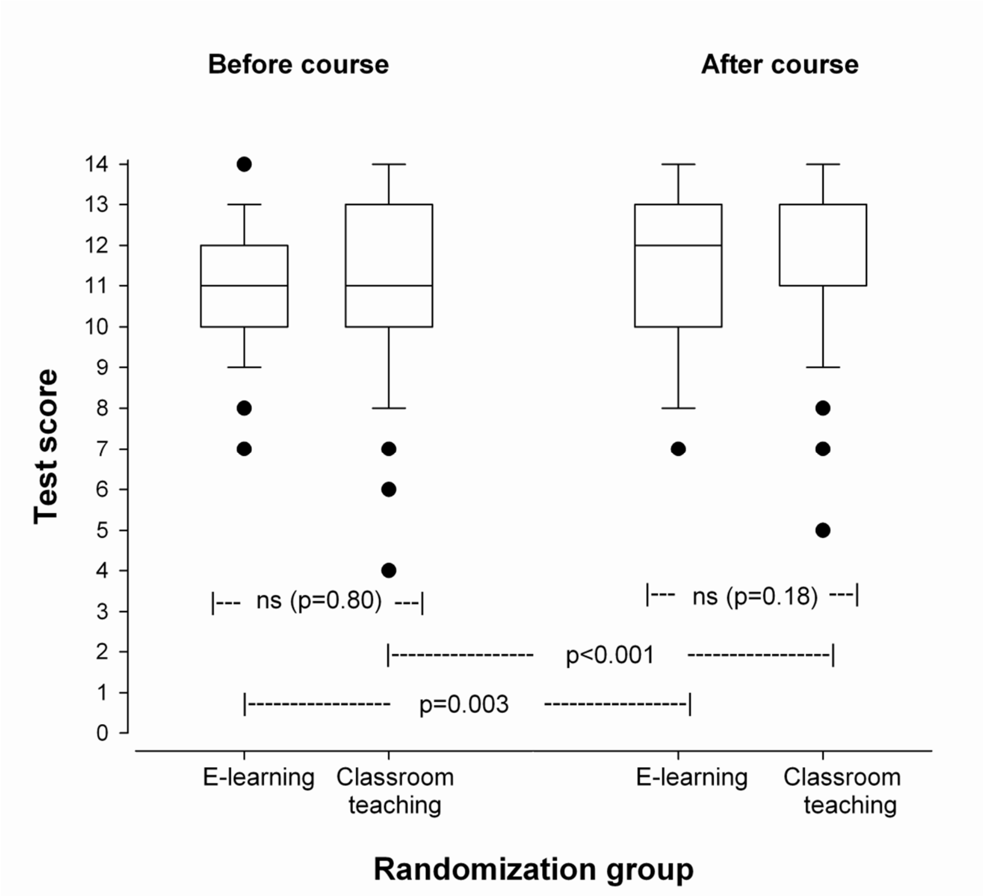
FIGURE LEGENDS

Figure 1 Participant flow chart

Figure 2 Test results in drug dose calculations



*) One of the hospitals randomized 59 participants to three courses, the two study courses, and a local e-learning course in drug management (not part of this study).
**) For some of the tests delivered electronically, the participants exited from the program without pressing the "Send"-button.


Before course
After course
Test score
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
|--- ns (p=0.80) ---|
|--- ns (p=0.18) ---|
|---------------- p<0.001 ----------------|
|---------------- p=0.003 ----------------|
E-learning
Classroom teaching
E-learning
Classroom teaching
Randomization group

CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	3
	2b	Specific objectives or hypotheses	3
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	3
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	ns
Participants	4a	Eligibility criteria for participants	3
	4b	Settings and locations where the data were collected	3
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	4
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	5-6
	6b	Any changes to trial outcomes after the trial commenced, with reasons	na
Sample size	7a	How sample size was determined	4
	7b	When applicable, explanation of any interim analyses and stopping guidelines	na
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	4
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	No
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	4
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	na

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	4
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	6
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	9 ,11
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	18
	13b	For each group, losses and exclusions after randomisation, together with reasons	18
Recruitment	14a	Dates defining the periods of recruitment and follow-up	3
	14b	Why the trial ended or was stopped	na
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	7
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	Tables
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Tables
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	Tables
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	9
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	na
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	14
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	13
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	11-13
Other information			
Registration	23	Registration number and name of trial registry	na
Protocol	24	Where the full trial protocol can be accessed, if available	Author
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	15

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

BMJ Open

Improvement of drug dose calculation by classroom teaching or e-learning: A randomized controlled trial in nurses

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Improvement of drug dose calculation by classroom teaching or e-learning: A randomized controlled trial in nurses

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Word count: 3.946

ABSTRACT

Introduction: Insufficient skills in drug dose calculations increase the risk for medication errors. Even experienced nurses may struggle with such calculations. Learning flexibility and cost considerations make e-learning interesting as an alternative to classroom teaching. This study compared the learning outcome and risk of error after a course in drug dose calculation for nurses with the two methods.

Methods: In a randomized, controlled, open study, nurses from hospitals and primary health care were randomized to either e-learning or classroom teaching. Before and after a two-days' course, the nurses underwent a multiple-choice test in drug dose calculations: fourteen tasks with four alternative answers (score 0-14), and a statement regarding certainty of each answer (score 0-3). High risk of error was being certain that incorrect answer was correct. The results are given as mean(SD).

Results: Sixteen men and 167 women participated in the study. Age were 42.0(9.5) and working experience 12.3(9.5) years. Total scores after e-learning and classroom teaching were 11.6(2.0) and 11.9(2.0) respectively (p=0.18,ns), and improvement were 0.5(1.6) and 0.9(2.2) respectively (p=0.07,ns). Classroom was significantly superior to e-learning among participants with pre-test score below 9. Factors in favour of e-learning was higher value for working situation. There was no difference in risk of error between the groups after the course (p=0.77).

Conclusions: The study showed no differences in learning outcome or risk of error between e-learning and classroom teaching in drug dose calculation. The overall learning outcome was small. Weak pre-course knowledge was associated with better outcome after classroom teaching.

ARTICLE SUMMARY

Strengths and limitations of this study

- Medication errors are often considered to be due to stressful working situations, lapses in attention, or disturbances. This study demonstrates that more basic and continuing training in drug dose calculation is needed to prevent errors.
- The method includes a certainty evaluation of each drug dose calculation, and a development of a new risk of error measurement framework.
- Choosing between classroom teaching and e-learning do not solve the underlying problem with poor numeracy.
- The controlled test conditions may be regarded as a limitation. Although the testing of drug dose calculation is perceived as stressful in itself, it is not equal to the time pressure or disturbances in a working situation, when errors occur.

INTRODUCTION

From international reviews and reports of adverse drug events, incorrect doses account for up to 1/3rd of the events.(1-3) Many health professionals find drug dose calculations difficult. The majority of medical students are unable to calculate the mass of a drug in solution correctly, and around half the doctors are unable to convert drug doses correctly from a percentage concentration or dilution to mass concentration.(4, 5) Both in hospitals and primary health care the nurses carry out the practical drug management after the physicians' prescriptions. In Norway, a faultless test in drug dose calculation during nursing education is required to become a registered nurse.(6) Both nursing students and experienced nurses have problems with drug dose calculations, and nursing students early in the program show limited basic skills in arithmetic.(7-10) We have shown a high risk of error in conversion of units in 10 % of registered nurses in an earlier study.(11)

E-learning was introduced with the Internet in the early 1990s, and has been increasingly used in the medical and health care educations. E-learning is independent of time and place, and the training is easier to organize in the health services than classroom teaching, and to a lower cost. A meta-analysis from 2009 summarized more than 200 studies in health professions education, and concluded that e-learning is associated with large positive effects compared with no intervention, but compared to other interventions the effects are generally small.(12) There is lack of drug dose calculation studies where different didactic methods are compared.

The objective of this study was to compare the learning outcome, certainty and risk of error in drug dose calculations after courses with either self-directed e-learning or conventional classroom teaching. Further aims were to study factors associated with the learning outcome and risk of error.

METHODS

Design

A randomized, controlled, open study with parallel group design.

Participants

Registered nurses working in two hospitals and three municipalities in Eastern Norway were recruited to participate in the study. Inclusion criteria were nurses with at least one year of work experience in 50 % part time job or more. Excluded were nurses working in outpatient clinics, those who did not administer drugs, and any who did not master Norwegian language sufficiently. The study was performed from September 2007 to April 2009.

Interventions

At inclusion, all participants completed a form with relevant background characteristics, and nine statements from the General Health Questionnaire (GHQ 30).(13) Quality of Life tools are often used to explore psychological well-being. The GHQ 30 contains the dimensions sense of coping and self esteem/well-being, and was used to evaluate to what extent the nurses' sense of coping affected their calculation skills. The nurses performed a multiple-choice (MCQ) test in drug dose calculation. The questions were standard calculation tasks for bachelor students in nursing at university colleges. The test was taken either on paper or on an Internet web site. The time available for the test was 1 hour, and the participants were allowed to use a calculator.

After the test, the nurses were randomized to one of two two-day courses in drug dose calculation. One group was assigned to a self directed, interactive internet based e-learning course developed at a Norwegian university college. The other was assigned to one day conventional classroom course and one day self study. The content of the two courses were the same: a review of the basic theory of the different types of calculations, followed by examples and exercises. The topics covered were conversion between units; formulas for dose, quantity and strength; infusions; and dilutions. The e-learning group continued with interactive tests, with hints and suggested solutions. They had access to a collection of tests with feedback on answers, and a compendium was available for print-out. The classroom group had one day with lecture covering the basic theory; exercises in groups; discussion in plenary session; and an individual test at the end of the day. The second day was self study, with a text book including exercises used at the same college.(14) Two to four weeks after the course, the nurses were re-tested in drug dose calculation with a similar MCQ test as the pre-test.

Sample size

Studies testing drug dose calculation in nurses have shown a mean score of 75 % (SD 15%) (15-17). In a study with 14 questions, this is equivalent to a score of 10.5 (SD 2.1). To detect difference of one correct answer between the two didactic methods with the strength of 0.8 and alfa<0.05, it was necessary to include 74 participants in each group. Because of likely dropouts, the aim was to randomize 180 participating nurses.

Randomization

At inclusion, each nurse was stratified according to five workplaces: internal medicine, surgery or psychiatric wards in hospitals, and nursing home or ambulatory care in primary health care. Immediately after submission of the pre-test, the participants were randomized to one of the two didactic methods, by predefined computer generated lists for each stratum.

DATA COLLECTION

Participant characteristics

The following background characteristics were recorded: age; gender; childhood and education as a nurse in or outside of Norway; length of work experience as a nurse in at least a 50 % part-time job; part time job percentage past 12 months; present workplace in a specific hospital department (surgery, internal medicine or psychiatry) or primary health care (nursing home or ambulatory care); and frequency of drug dose calculation tasks at work, score 0-3: 0=less than monthly, 1=monthly, 2= weekly, 3=every working day. Further educational background was recorded (yes/no): mathematics beyond the first mandatory year at upper secondary school; other education prior to nursing; postgraduate specialization; and courses in drug dose calculation during the latest three years. The participants registered motivation for the courses in drug dose calculation, rated as 1=very unmotivated, 2=relatively unmotivated, 3=relatively motivated, 4= very motivated

In addition, the participants were asked to consider statements from GHQ30, in the context of performing medication tasks: five regarding coping (finding life a struggle; being able to enjoy normal activities; feeling reasonably happy; getting scared or panicky for no good reason; and being capable of making decisions), and four regarding self esteem/well-being (overall doing things well; satisfied with the way they have carried out their task; managing to keep busy and occupied; and managing as well as most people in the same situation). The ratings of these statements were 0-3: 0=more/better than usual, 1=as usual, 2=less/worse than usual, and 3=much less/worse than usual; "as usual" was defined as the normal state.

Outcomes

Drug dose calculation test and certainty in the calculations

A drug dose calculation test was performed before and after the course: 14 MCQs with four alternative answers. The topics were as follows (number of questions in brackets): conversion of units (7), formulas for calculation of dose, quantity or strength (4), infusions (2), and dilutions (1). For each question, the participants indicated a self-estimated certainty, graded from 0-3: 0=very uncertain, and would search for help, 1=relatively uncertain, and would probably search for help, 2=relatively certain, and would probably not search for help, and 3=very certain, and would not search for help. The questionnaires used is enclosed as Additional file 1

Risk of error

Risk of error was estimated by combining knowledge and certainty for each question rated on a scale from 1 to 3, devised for the study. Correct answer combined with relatively or high certainty was regarded as a low risk of error (score=1), any answer combined with relatively or very low certainty was regarded as a moderate risk of error (score=2), and incorrect answer combined with relatively or high certainty was regarded as a high risk of error (score=3).

Course evaluation

After the course, the nurses recorded their assessment of the level of difficulty of the course related to their own prior knowledge (1=very difficult, 2=relatively difficult, 3=relatively easy, 4 =very easy); and course satisfaction (1=very unsatisfied, 2=relatively unsatisfied, 3=relatively satisfied, 4=very satisfied). An evaluation of the usefulness of the specific course in drug dose calculation in daily work as a nurse was rated from 1=very small, 2=relatively small, 3=relatively large to 4=very large.

Ethical considerations

The Norwegian Data Inspectorate, represented by Privacy Ombudsman for Research, approved the study. Further ethics committee approval was not applicable. All participants gave written informed consent. The tests were performed de-identified. A list connecting the study participant number to the names was kept until after the re-test, in case any of the participants had forgotten their number. To protect the participants from any consequences because of the test, the data were made anonymous before the analysis.

Even if the study might uncover that individuals showed a high risk of medication errors due to lacking calculation skills, it was considered ethically justifiable not to be able to expose their identity to their employer.

Data analysis

The analysis was performed with intention-to-treat analyses. In addition, a per protocol analysis was performed for the main results. Depending on data distribution, comparisons between groups were analyzed with Chi-square or Fishers exact test, t-test or Mann-Whitney U-test, ANOVA, Friedman, and Pearson or Spearman tests for correlations, and Wilcoxon signed rank test for paired comparisons before and after course. All variables possibly associated with learning outcome and change in risk of error were entered in linear regression analyses to identify independent predictors (18). Two-tailed significance tests were used, and a p-value < 0.05 was considered statistically significant.

The protocol contained instructions for handling of missing data. Unanswered questions were scored as "incorrect answer," and unanswered certainty score as "very uncertain". For participants who did not take the test after course, the result from the pre-test ("last observation") was carried forward. The analysis was performed with SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). All results are given as mean and (SD) if not otherwise indicated.

RESULTS

In total, 212 registered nurses were included in the study, and 183 were eligible for randomization. **Figure 1** shows the flow of participants throughout the study, and **Table 1** summarizes the participant characteristics and the pre-test results. The two groups were well balanced with respect to baseline characteristics. Of the 183 nurses, 79 (43%) were recruited from hospitals (48 from surgery departments, including intensive care units; 23 from internal medicine wards; 8 from psychiatric wards), and 104 (57 %) from primary health care (52 from nursing homes and 52 from ambulatory health care). Nearly half of the nurses (48 %) performed drug dose calculations weekly or more often.

There was a tendency for more dropouts in the e-learning group; 18.4 % vs. 9.9 % (p=0.10). The dropouts did not differ from those who completed the study regarding workplace: 12 from hospitals and 14 from primary health care (p=0.74), or pre-test result: score 10.5 vs. 11.1, 95% CI for difference -1.5:+0.2, (p=0.13).

Table 1 Participants' characteristics and pre-test results

	E-learning (n=92)	Classroom (n=91)	P-value
Participants` characteristics			
Age (years)	41.6 (8.8)	42.4 (10.1)	0.57
Gender (men)	8 (8.7 %)	8 (8.8 %)	0.98
Childhood outside Norway	7 (7.6 %)	7 (7.7 %)	0.98
Nurse education outside Norway	5 (5.4 %)	4 (4.4 %)	0.75
Work experience as nurse (years)	12.8 (9.6)	11.7 (9.3)	0.44
Part time job latest 12 months (full time=1)	0.84 (0.18)	0.88 (0.15)	0.13

Working in hospital	42 (45.7 %)	37 (40.7 %)	0.50
Frequency of drug dose calculation tasks at work (0-3) [2)]	1.5 (1.1)	1.3 (1.1)	0.28
Mathematics beyond 1st year high-school/USS[1)]	38 (41.3 %)	38 (41.8 %)	0.95
Other education before becoming a nurse	37 (40.2 %)	41 (45.1 %)	0.51
Postgraduate specialization	31 (33.7 %)	26 (28.6 %)	0.45
Course in drug dose calculation latest 3 years	9 (9.8 %)	13 (14.3 %)	0.35
Motivation for course in drug dose calculation (1-4)	3.3 (0.5)	3.2 (0.5)	0.12
Pre-test results			
Sense of coping (0-3)[3)]	0.79 (0.25)	0.81 (0.31)	0.60
Sense of self esteem/well-being (0-3) [3)]	1.01 (0.18)	1.03 (0.21)	0.45
Knowledge (score 0-14)	11.1 (1.7)	11.0 (2.3)	0.80
Certainty (score 0-3)	2.1 (0.6)	1.9 (0.6)	0.35
Risk of error (score 1-3)	1.4 (0.2)	1.5 (0.3)	0.27

The results are given as mean (standard deviation in brackets), or number of participants (proportion in brackets).
[1)] Upper secondary school
[2)] Scale: 0= less than monthly, 1= monthly, 2= weekly, 3= every working day.
[3)] Scale: 0= more/better than usual, 1= as usual, 2=less/worse than usual, 3= much less/worse than usual. Statistical tests: T-test, Mann-Withney U-test, Chi-square test, Fisher exact test.

Knowledge, learning outcome and risk of error

The test results before and after course are shown in **figure 2**, and the upper part of **table 2** gives the main results after e-learning and classroom teaching. No significant difference between the two didactic methods were detected for overall test score, certainty or risk of error. The overall knowledge score improved from 11.1 (2.0) to 11.8 (2.0), ($p<0.001$). Before and after the course, 20 (10.9 %) and 37 (20.2 %) participants, respectively, completed a faultless test. The overall risk of error decreased after course; from 1.5 (0.3) to 1.4 (0.3), ($p<0.001$), but 41 nurses (22 %) showed an increased risk; 20 from the e-learning group and 21 from the classroom group. This proportion is within the limits of what could appear by coincidence from a normal distribution (24 %), and the mean learning outcome of 0,7 (0.2).

Table 2 Main results after course in drug dose calculations

	Results after course			Changes from pre-test		
	E-learning	Classroom	p-value	E-learning	Classroom	P-value
All participants	n=92	n=91		n=92	n=91	

Test score (score 0-14)	11.6 (2.0)	11.9 (2.0)	0.18	0.5 (1.6)	0.9 (2.2)	0.07
- Conversion of Units (0-7)	5.5 (1.3)	6.0 (1.2)	0.005	0.3 (1.2)	0.9 (1.5)	0.04
- Dose-quantity-strength (0-4)	3.6 (0.6)	3.4 (0.8)	0.12	0.2 (0.7)	0.03 (0.7)	0.86
- Infusions (0-2)	1.7 (0.5)	1.7 (0.5)	0.64	0.01 (0.4)	0.02 (0.7)	0.21
- Dilutions (0-1)	0.8 (0.4)	0.8 (0.4)	0.98	0.05 (0.4)	0.01 (0.5)	0.90
Certainty (score 0-3)	2.3 (0.5)	2.2 (0.6)	0.24	0.2 (0.6)	0.3 (0.6)	0.27
Risk of error (score 1-3)	1.4 (0.3)	1.4 (0.3)	0.77	-0.1 (0.2)	-0.1 (0.3)	0.29
Participants with						
pre-test score ≥ 9 [1)]	n=85	n=76		n=85	n=76	
Test score (score 0-14)	11.9 (1.8)	12.2 (1.9)	0.29	0.5 (1.6)	0.4 (1.8)	0.74
Certainty (score 0-3)	2.3 (0.5)	2.2 (0.7)	0.18	0.2 (0.6)	0.3 (0.7)	0.73
Risk of error (score 1-3)	1.3 (0.3)	1.4 (0.3)	0.61	-0.1 (0.2)	-0.1 (0.3)	0.92
pre-test score < 9 [1)]	n=7	n=15		n=7	n=15	
Test score (score 0-14)	8.4 (0.3)	10.7 (2.2)	0.01	0.7 (1.3)	3.6 (1.8)	0.001
Certainty (score 0-3)	1.9 (0.5)	2.0 (0.5)	0.74	0.2 (0.7)	0.4 (0.4)	0.40
Risk of error (score 1-3)	1,7 (0.2)	1.5 (0.2)	0.03	-0.1 (0.2)	-0.3 (0.3)	0.04

Results are given as mean (SD)
[1)] Auxiliary sub group analysis
Statistical test: Mann-Withney U-test

An analysis of the main results from the 141 participants who completed the study according to protocol, generally showed the same as the intention to treat analysis, with no difference between the two didactic methods. The overall knowledge score improved from 11.1 (2.0) to 12.0 (2.0) ($p<0.001$).

Table 3 gives the results as proportion of correct answers and the proportion of answers with a high risk of error within each calculation topic before and after course. The test results in each topic for the two didactic methods showed that the classroom group scored significantly better after course in conversion of units: 86 % correct answers vs. 78 %, $p<0.001$, with no difference in the other topics. Overall, there were significant differences between the four topics in knowledge and risk of error both before and after course, $p<0.001$ (Friedman's test). Sense of coping or self esteem/well-being was not affected by the course for neither of the groups, data not shown.

Table 3 Knowledge and high risk of error within each calculation topic before and after course

	Proportion of correct answers (n=183)			Proportion of answers with a high risk of error (score=3) (n=183)		
Topic (number of questions)	Before course	After course	P-value	Before course	After course	P-value

Conversion of Units (7)	73.9(20.2)	81.8(18.9)	<0.001	10.6(14.6)	10.6(14.7)	0.93
Dose-quantity-strength(4)	84.7(16.9)	87.2(17.2)	0.06	3.0 (8.2)	5.0 (11.1)	0.02
Infusions (2)	83.5(27.8)	84.4(26.0)	0.70	4.0(16.1)	4.0 (15.6)	0.87
Dilutions (1)	81.4(39.0)	84.7(36.1)	0.32	6.0(23.8)	5.0 (22.8)	0.80
In total (14)	78.9(14.3)	83.9(14.5)	<0.001	7.1 (9.6)	7.7 (9.6)	0.51

Results are given as mean (SD).
Statistical test: Wilcoxon signed rank test, Friedman's test

Factors significantly associated with good learning outcome and reduction in the risk of error after course is given in **Table 4.** Among these factors, the randomization to classroom teaching was significantly better in learning outcome, adjusted for other variables. Both low pre-test knowledge and certainty score were associated with reduced risk of error after course, as were being a man and working in hospital. Self-evaluations of coping and self esteem/well-being were neither associated with learning outcome nor risk of error. The total R^2 change for the variables significantly associated with good learning outcome and risk of error were 0.28 and 0.18, respectively.

Table 4 Factors significantly associated with learning outcome and reduction in risk of error after course in drug dose calculation

	Learning outcome		**Reduction in risk of error**	
	Beta	***P-value***	***Beta***	***P-value***
Sex (man)			0.20	0.006
Working in hospital	0.21	0.02	0.26	0.005
Pre-test knowledge score	-0.61	<0.001	-0.29	0.001
Pre-test certainty score			-0.25	0.003
Randomization – classroom	0.16	0.02		
Motivation for course	0.17	0.02		

Multivariable regression analysis with all participant characteristics included as possible factors (n=183).
Statistical test: Linear regression analysis, after bivariable correlation tests Pearson and Spearman

Course evaluation

Nearly all (97.5 %) of the participants stated a need for training courses in drug dose calculation. The evaluation after the course showed no difference between the didactic methods in expressed degree of difficulty or course satisfaction, data not shown.. The specific value of the course for working situation was scored 3.1 (0.7) in the e-learning group and 2.7 (0.7) in the classroom group (p<0.001).

Auxiliary analyses

A posthoc analysis for sub groups with pre-test knowledge score $\geq$ 9 and <9 is given in the lower part of **table 2**. For the participants with low pre-score, classroom teaching gave significantly better learning outcome and reduced risk of error after course. The overall knowledge score improved in the high score group from 11.6 (1.4) to 12.0 (1.9) and in the low score group from 7.2 (1.0) to 9.9 (2.3), and the difference in learning outcome was highly significant (p<0.001).

DISCUSSION

Drug dose calculation skills

The study was not able to demonstrate an overall difference in learning outcome between the two didactic methods, neither of statistical nor clinical importance. Both methods resulted in improvement of drug dose calculations after course, although the learning outcome was smaller than what was defined as clinically relevant. Adjusted for other contributing factors for learning outcome in the multivariable analysis, the classroom method was statistically superior to e-learning, and so was the case for a sub group with low pre-test result. This finding from the post hoc analysis was probably the only outcome that could have a meaningful practical implication for choice of learning strategy, if reproduced in new studies. These results were in accordance with a meta-analysis of 201 trials comparing e-learning with other methods.(19) The review summarized that any educational action gives positive outcome, regardless of method. E-learning works compared to no intervention, but tested against conventional methods it is difficult to detect any differences.

Drug dose calculations are not advanced in a mathematical sense. The basic arithmetic functions of addition, subtraction, multiplication or division are needed to decide decimals and fractions. What seems to be challenging is to conceptually understand the difference in information from the concentration denomination: percent or mass per unit volume, or the ability to set up the right calculation for the relationship between dose or mass, volume or amount and concentration or strength. A standard labelling to mass per unit volume has been strongly recommended.(20, 21)

The fact that only one out of ten nurses performed a faultless pre-test was not surprising, from what is previously shown. In a study by McMullan only 5 % of the nurses achieved 80 % correct calculations.(22) Although statistically significant, the limited overall learning outcome after the courses was somewhat disappointing, with only two out of ten with faultless tests. It seemed that the incorrect calculations were more frequent in conversion of units, the least complex task in mathematical sense. The conversion of units improved the most after course, while the learning outcome in the arithmetic tasks of infusions and dilutions were unchanged. This has also been observed by other investigators, and support the view that the challenges in drug dose calculation is more likely due to poor conceptual understanding.(10) Recent papers address the importance of including both conceptual (understanding the problem), calculation (dosage computation) and technical measurement (dosage measurement) competence in teaching nurses in vocational mathematics, with models to help them understand the" what", the" why" and the "how" in dosage problem-solving. (23, 24)

Risk of error

The study was not able to demonstrate any difference in the risk of error between the e-learning and classroom groups, neither before nor after course. Asking for certainty in each calculation made it possible for the nurses to express whether they normally would have consulted others or not when doing the calculation. Being certain that an incorrect answer was correct, was regarded as an adequate estimate for high risk of error To our knowledge, such method for estimating a risk of error from a test situation is not described by others, and may be a contribution to future research. Due to the low learning outcome, one could fear that increased certainty would lead to increased risk of error. Therefore, it was satisfying that the overall risk of error declined after course with both methods. Although a proportion of 22 % with increased risk of error after taking the course seemed alarming, it was within the limit of what could occur by chance, due to the small learning outcome. However, one may speculate if an increased risk may be due to some participants felt safer, but not obtained increased knowledge. This might have implications for the need of follow-up after courses.

The factors that were associated with reduced risk of error after the calculation course could indicate who might benefit from training like this: being a man; working in hospital; low pre-test score; and low pre-test certainty score. This supports the finding in the auxiliary analysis; that nurses with weak drug dose calculation skills benefit most from taking courses. Nevertheless, the risk of error demonstrated in the study did not necessarily reflect the real risk of adverse event affecting patients, as the test situation cannot measure how often miscalculations were performed or how serious the clinical implications might be for any patient. Such studies still need to be done.

Importance for practice

The fact that 48 % of the participants in the study performed drug dose calculations at least weekly was more than anticipated. It has been a common perception that the need for most nurses to calculate drug doses is small in today's clinical practice. The reported extent of calculations underscores the importance of good skills in this field.

When the need for continuous improvement and maintenance of skills are identified, the time and resources available will be decisive for the possibility to implement further training activities. E-learning is more often a preferred choice in health services institutions, as it is both flexible and cost effective. In our study the e-learning group stated a higher specific value of the course for working situation, although the course content was similar in both methods. But this method also had more dropouts and lesser learning outcome for those with low skills. In a review article commenting upon the results of a meta-analysis of e-learning and conventional instruction methods, Cook claims that rather than more comparative studies, further research should focus on under which conditions ("how and when") e-learning is a preferable method.(12)

An implication of the findings can be to let nurses regularly perform an e-learning course followed by a screening test to uncover the weak calculation topics. Those who need further training should be offered a more tailored follow-up. Others have also documented that a combination of different learning and teaching strategies do result in better retention of drug calculation skills compared to lectures alone.(23) Further studies of the effect of the introduction of drug dose calculation apps would also be of interest, as well as more authenthic observation studies in high fidelity simulation environment, as reported from a Scottish HHS study. (26)

Interestingly, the e-learning group stated a higher specific value of the course for working situation, although the course content was similar in both methods. This may be explained by the flexibility of the e-learning course, allowing the participants to concentrate on the items that were considered difficult and relevant for their work, while the classroom group had to follow through the whole programme. Nearly all the nurses realized themselves that they need more training in drug dose calculations, and an important factor was that motivation for course was associated with good learning outcome in the study. This indicates that the professional leadership in health institutions should facilitate and encourage the nurses to improve their skills further in drug dose calculations.

I addition to regularly training in calculations, written procedures for specific dilutions and infusions used in the wards would be of importance as a quality insurance for improved patient safety. This must be a part of the management responsibility.

Study limitations

The participants in this study were recruited through the management line, and the study population represents a limited part of the total nurse population. We assume that nurses with low calculation skills to a lesser degree would volunteer for such a study, and hence presume that the calculation skills in clinical practice would be lower than shown in this study. External validity might be an issue in studies with voluntary participation, and extrapolation of the findings of the study to all registered nurses should be performed with caution.

Some may question the quality of the course content and duration or teaching conditions of the courses, especially since the learning outcome of the courses were not convincing. However, the main aim for the study was to compare the two didactic methods. And, to ensure a fair comparison and similar content of the courses, the subject teacher who was a part of the group that developed the e-learning course, also was responsible for the classroom lectures. Since the teacher had an interest in both didactic methods, the probability for her to affect the course arrangements in favour of one of them was regarded as small. The questionnaire used was the same as nursing students were tested by, and the calculation tasks were considered to be in accordance with the tasks that were done in the nursing practice.

Another limitation could be the controlled test conditions, without time pressure and interruptions that are often the case in a stressful work situation, which tend towards better results than in reality. On the other hand, the calculation test situation itself may be stressful for the nurses, since many have struggled to pass a similar test during their studies.

Selecting two dimensions from the GHQ30 questionnaire may also be a methodological limitation. Although no correlation between the outcomes and coping or well-being/self esteem were detected, the usage of only parts of the tool excluded the possibility of detecting an association between physiological well-being in general and drug dose calculation skills.

CONCLUSION

The study was not able to demonstrate any differences between e-learning and classroom teaching in drug dose calculation, with respect to learning outcome, certainty or risk of error. The overall learning outcome was without practical significance, and conversion of units was the only topic that was significantly improved after course. An independent factor in favour of classroom teaching was weak pre-test knowledge, while factors suggesting use of e-learning could be the need for training in relevant work specific tasks and time effective repetition.

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Competing interests

BOS, IJ and PGF: None

GKD was part of the group who developed the e-learning programme used in the study, and the course was made commercially available from autumn 2009.

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FIGURE LEGENDS

Figure 1 Participant flow chart

Figure 2 Test results in drug dose calculations

Improvement of drug dose calculation by classroom teaching or e-learning: A randomized controlled trial in nurses

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ABSTRACT

Introduction: Insufficient skills in drug dose calculations increase the risk for medication errors. Even experienced nurses may struggle with such calculations. Learning flexibility and cost considerations make e-learning interesting as an alternative to classroom teaching. This study compared the learning outcome and risk of error after a course in drug dose calculation for nurses with the two methods.

Methods: In a randomized, controlled, open study, nurses from hospitals and primary health care were randomized to either e-learning or classroom teaching. Before and after a two-days' course, the nurses underwent a multiple-choice test in drug dose calculations: fourteen tasks with four alternative answers (score 0-14), and a statement regarding certainty of each answer (score 0-3). High risk of error was being certain that incorrect answer was correct. The results are given as mean(SD).

Results: Sixteen men and 167 women participated in the study. Age were 42.0(9.5) and working experience 12.3(9.5) years. Total scores after e-learning and classroom teaching were 11.6(2.0) and 11.9(2.0) respectively (p=0.18,ns), and improvement were 0.5(1.6) and 0.9(2.2) respectively (p=0.07,ns). Classroom was significantly superior to e-learning among participants with pre-test score below 9. Factors in favour of e-learning was ~~less time consumption, and~~ higher value for working situation. There was no difference in risk of error between the groups after the course (p=0.77).

Conclusions: The study showed no differences in learning outcome or risk of error between e-learning and classroom teaching in drug dose calculation. The overall learning outcome was small. Weak pre-course knowledge was associated with better outcome after classroom teaching.

ARTICLE SUMMARY

Strengths and limitations of this study

- Medication errors are often considered to be due to stressful working situations, lapses in attention, or disturbances. This study demonstrates that more basic and continuing training in drug dose calculation is needed to prevent errors.
- The method includes a certainty evaluation of each drug dose calculation, and a development of a new risk of error measurement framework. ~~which contributes to identify areas with high risk of error.~~
- Choosing between classroom teaching and e-learning do not solve the underlying problem with poor numeracy.
- The controlled test conditions may be regarded as a limitation. Although the testing of drug dose calculation is perceived as stressful in itself, it is not equal to the time pressure or disturbances in a working situation, when errors occur.

INTRODUCTION

From international reviews and reports of adverse drug events, incorrect doses account for up to 1/3rd of the events.(1-3) ManyMost health professionals find drug dose calculations difficult. The majority of medical students are unable to calculate the mass of a drug in solution correctly, and around half the doctors are unable to convert drug doses correctly from a percentage concentration or dilution to mass concentration.(4, 5) Both in hospitals and primary health care the nurses carry out the practical drug management after the physicians' prescriptions. In Norway, a faultless test in drug dose calculation during nursing education is required to become a registered nurse.(6) Both nursing students and experienced nurses have problems with drug dose calculations, and nursing students early in the program show limited basic skills in arithmetic.(7-10) We have shown a high risk of error in conversion of units in 10 % of registered nurses in an earlier study.(11)

E-learning was introduced with the Internet in the early 1990s, and has been increasingly used in the medical and health care educations. E-learning is independent of time and place, and the training is easier to organize in the health services than classroom teaching, and to a lower cost. A meta-analysis from 2009 summarized more than 200 studies in health professions education, and concluded that e-learning is associated with large positive effects compared with no intervention, but compared to other interventions the effects are generally small.(12) There is lack of drug dose calculation studies where different didactic methods are compared.

The objective of this study was to compare the learning outcome, certainty and risk of error in drug dose calculations after courses with either self-directed e-learning or conventional classroom teaching. Further aims were to study factors associated with the learning outcome and risk of error.

METHODS

Design

A randomized, controlled, open study with parallel group design.

Participants

Registered nurses working in two hospitals and three municipalities in Eastern Norway were recruited to participate in the study. Inclusion criteria were nurses with at least one year of work experience in 50 % part time job or more. Excluded were nurses working in outpatient clinics, those who did not administer drugs, and any who did not master Norwegian language sufficiently. The study was performed from September 2007 to April 2009.

Interventions

At inclusion, all participants completed a form with relevant background characteristics, and nine statements from the General Health Questionnaire (GHQ 30).(13) Quality of Life tools are often used to explore psychological well-being. The GHQ 30 contains the dimensions sense of coping and self esteem/well-being, and was used to evaluate to what extent the nurses' sense of coping affected their calculation skills. The nurses performed a multiple-choice (MCQ) test in drug dose calculation. The questions were standard calculation tasks for bachelor students in nursing at university colleges. The test was taken either on paper or on an Internet web site. The time available for the test was 1 hour, and the participants were allowed to use a calculator.

After the test, the nurses were randomized to one of two two-day courses in drug dose calculation. One group was assigned to a self directed, interactive internet based e-learning course developed at a Norwegian university college. The other was assigned to one day conventional classroom course and one day self study. with lectures, exercises and text book, used at the same college.(14) The content of the two courses were the same: a review of the basic theory of the different types of calculations, followed by examples and exercises. The topics covered were conversion between units; formulas for dose, quantity and strength; infusions; and dilutions. The e-learning group continued with interactive tests, with hints and suggested solutions. They had access to a collection of tests with feedback on answers, and a compendium was available for print-out. The classroom group had one day with lectures covering the basic theory; , exercises in groups; discussion in plenary session; and an individual test at the end of the day. The second day was self study, and with a text book including exercises , used at the same college.(14) Two to four weeks after the course, the nurses were re-tested in drug dose calculation with a similar MCQ test as the pre-test.

Sample size

Studies testing drug dose calculation in nurses have shown a mean score of 75 % (SD 15%) (15-17). In a study with 14 questions, this is equivalent to a score of 10.5 (SD 2.1). To detect difference of one correct answer between the two didactic methods with the strength of 0.8 and alfa<0.05, it was necessary to include 74 participants in each group. Because of likely dropouts, the aim was to randomize 180 participating nurses.

Randomization

At inclusion, each nurse was stratified according to five workplaces: internal medicine, surgery or psychiatric wards in hospitals, and nursing home or ambulatory care in primary health care. Immediately after submission of the pre-test, the participants were randomized to one of the two didactic methods, by predefined computer generated lists for each stratum.

DATA COLLECTION

Participant characteristics

The following background characteristics were recorded: age; gender; childhood and education as a nurse in or outside of Norway; length of work experience as a nurse in at least a 50 % part-time job; part time job percentage job size past 12 months; present workplace in a specific hospital department (surgery, internal medicine or psychiatry) or primary health care (nursing home or ambulatory care); and frequency of drug dose calculation tasks at work, score 0-3: 0=less than monthly, 1=monthly, 2= weekly, 3=every working day. Further educational background was recorded (yes/no): mathematics beyond the first mandatory year at upper secondary school; other education prior to nursing; postgraduate specialization; and courses in drug dose calculation during the latest three years. The participants registered motivation for the courses in drug dose calculation, rated as 1=very unmotivated, 2=relatively unmotivated, 3=relatively motivated, 4= very motivated

In addition, the participants were asked to consider statements from GHQ30, in the context of performing medication tasks: five regarding coping (finding life a struggle; being able to enjoy normal activities; feeling reasonably happy; getting scared or panicky for no good reason; and being capable of making decisions), and four regarding self esteem/well-being (overall doing things well; satisfied with the way they have carried out their task; managing to keep busy and occupied; and managing as well as most people in the same situation). The ratings of these statements were 0-3: 0=more/better than usual, 1=as usual, 2=less/worse than usual, and 3=much less/worse than usual; "as usual" was defined as the normal state.

Outcomes

Drug dose calculation test and certainty in the calculations

A drug dose calculation test was performed before and after the course: 14 multiple choice questionsMCQs with four alternative answers. The topics were as follows (number of questions in brackets): conversion of units (7), formulas for calculation of dose, quantity or strength (4), infusions (2), and dilutions (1). For each question, the participants indicated a self-estimated certainty, graded from 0-3: 0=very uncertain, and would search for help, 1=relatively uncertain, and would probably search for help, 2=relatively certain, and would probably not search for help, and 3=very certain, and would not search for help. The questionnaires used is enclosed as Additional file Appendix 1

Risk of error

Risk of error was estimated by combining knowledge and certainty for each question rated on a scale from 1 to 3, devised for the study. Correct answer combined with relatively or high certainty was regarded as a low risk of error (score=1), any answer combined with relatively or very low certainty was regarded as a moderate risk of error (score=2), and incorrect answer combined with relatively or high certainty was regarded as a high risk of error (score=3).

Course evaluation

After the course, the nurses recorded their ~~time spent for self study (0-3 hours, 3-6, 6-9, 9-12, 12-15, more than 15 hours);~~ assessment of the level of difficulty of the course related to their own prior knowledge (1=very difficult, 2=relatively difficult, 3=relatively easy, 4 =very easy); and course satisfaction (1=very unsatisfied, 2=relatively unsatisfied, 3=relatively satisfied, 4=very satisfied). An evaluation of the usefulness of the specific course in drug dose calculation in daily work as a nurse was rated from 1=very small, 2=relatively small, 3=relatively large to 4=very large.

Ethical considerations

The Norwegian Data Inspectorate, represented by Privacy Ombudsman for Research, approved the study. Further ethics committee approval was not applicable. All participants gave written informed consent. The tests were performed de-identified. A list connecting the study participant number to the names was kept until after the re-test, in case any of the participants had forgotten their number. To protect the participants from any consequences because of the test, the data were made anonymous before the analysis.

Even if the study might uncover that individuals showed a high risk of medication errors due to lacking calculation skills, it was considered ethically justifiable not to be able to expose their identity to their employer.

Data analysis

The analysis was performed with intention-to-treat analyses. In addition, a per protocol analysis was performed for the main results. Depending on data distribution, comparisons between groups were analyzed with Chi-square or Fishers exact test, t-test or Mann-Whitney U-test, ANOVA, Friedman, and Pearson or Spearman tests for correlations, and Wilcoxon signed rank test for paired comparisons before and after course. All variables possibly associated with learning outcome and change in risk of error were entered in linear ~~standard multiple~~ regression analyses to identify independent predictors (18). Two-tailed significance tests were used, and a p-value < 0.05 was considered statistically significant.

The protocol contained instructions for handling of missing data. Unanswered questions were scored as "incorrect answer," and unanswered certainty score as "very uncertain". For participants who did not take the test after course, the result from the pre-test ("last observation") was carried forward. The analysis was performed with SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). All results are given as mean and (SD) if not otherwise indicated.

RESULTS

In total, 212 registered nurses were included in the study, and 183 were eligible for randomization. **Figure 1** shows the flow of participants throughout the study, and **Table 1** summarizes the participant characteristics and the pre-test results. The two groups were well balanced with respect to baseline characteristics. Of the 183 nurses, 79 (43%) were recruited from hospitals (48 from surgery departments, including intensive care units; 23 from internal medicine wards; 8 from psychiatric wards), and 104 (57 %) from primary health care (52 from nursing homes and 52 from ambulatory health care). Nearly half of the nurses (48 %) performed drug dose calculations weekly or more often.

There was a tendency for more dropouts in the e-learning group; 18.4 % vs. 9.9 % (p=0.10). The dropouts did not differ from those who completed the study regarding workplace: 12 from hospitals and 14 from primary health care (p=0.74), or pre-test result: score 10.5 vs. 11.1, 95% CI for difference -1.5:+0.2, (p=0.13).

Table 1 Participants' characteristics and pre-test results

	E-learning (n=92)	Classroom (n=91)	P-value
Participants` characteristics			
Age (years)	41.6 (8.8)	42.4 (10.1)	0.57
Gender (men)	8 (8.7 %)	8 (8.8 %)	0.98
Childhood outside Norway	7 (7.6 %)	7 (7.7 %)	0.98
Nurse education outside Norway	5 (5.4 %)	4 (4.4 %)	0.75
Work experience as nurse (years)	12.8 (9.6)	11.7 (9.3)	0.44

Part time job~~Job size~~ latest 12 months (full time=1)	0.84 (0.18)	0.88 (0.15)	0.13
Working in hospital	42 (45.7 %)	37 (40.7 %)	0.50
Frequency of drug dose calculation tasks at work (0-3) [2)]	1.5 (1.1)	1.3 (1.1)	0.28
Mathematics beyond 1st year high-school/USS[1)]	38 (41.3 %)	38 (41.8 %)	0.95
Other education before becoming a nurse	37 (40.2 %)	41 (45.1 %)	0.51
Postgraduate specialization	31 (33.7 %)	26 (28.6 %)	0.45
Course in drug dose calculation latest 3 years	9 (9.8 %)	13 (14.3 %)	0.35
Motivation for course in drug dose calculation (1-4)	3.3 (0.5)	3.2 (0.5)	0.12
Pre-test results			
Sense of coping (0-3)[3)]	0.79 (0.25)	0.81 (0.31)	0.60
Sense of self esteem/well-being (0-3) [3)]	1.01 (0.18)	1.03 (0.21)	0.45
Knowledge (score 0-14)	11.1 (1.7)	11.0 (2.3)	0.80
Certainty (score 0-3)	2.1 (0.6)	1.9 (0.6)	0.35
Risk of error (score 1-3)	1.4 (0.2)	1.5 (0.3)	0.27

The results are given as mean (standard deviation in brackets), or number of participants (proportion in brackets).
1) Upper secondary school
2) Scale: 0= less than monthly, 1= monthly, 2= weekly, 3= every working day.
3) Scale: 0= more/better than usual, 1= as usual, 2=less/worse than usual, 3= much less/worse than usual.
Statistical tests: T-test, Mann-Withney U-test, Chi-square test, Fisher exact test.

Knowledge, learning outcome and risk of error

The test results before and after course are shown in **figure 2**, and the upper part of **table 2** gives the main results after e-learning and classroom teaching. No significant difference between the two didactic methods were detected for overall test score, certainty or risk of error. The overall knowledge score improved from 11.1 (2.0) to 11.8 (2.0), ($p<0.001$). Before and after the course, 20 (10.9 %) and 37 (20.2 %) participants, respectively, completed a faultless test. The overall risk of error decreased after course; from 1.5 (0.3) to 1.4 (0.3), ($p<0.001$), but 41 nurses (22 %) showed an increased risk; 20 from the e-learning group and 21 from the classroom group. This proportion is within the limits of what could appear by coincidence from a normal distribution (24 %), and the mean learning outcome of 0,7 (0.2).

Table 2 Main results after course in drug dose calculations

	Results after course			Changes from pre-test		
	E-learning	Classroom	p-value	E-learning	Classroom	P-value

All participants	n=92	n=91		n=92	n=91	
Test score (score 0-14)	11.6 (2.0)	11.9 (2.0)	0.18	0.5 (1.6)	0.9 (2.2)	0.07
- Conversion of Units (0-7)	5.5 (1.3)	6.0 (1.2)	0.005	0.3 (1.2)	0.9 (1.5)	0.04
- Dose-quantity-strength (0-4)	3.6 (0.6)	3.4 (0.8)	0.12	0.2 (0.7)	0.03 (0.7)	0.86
- Infusions (0-2)	1.7 (0.5)	1.7 (0.5)	0.64	0.01 (0.4)	0.02 (0.7)	0.21
- Dilutions (0-1)	0.8 (0.4)	0.8 (0.4)	0.98	0.05 (0.4)	0.01 (0.5)	0.90
Certainty (score 0-3)	2.3 (0.5)	2.2 (0.6)	0.24	0.2 (0.6)	0.3 (0.6)	0.27
Risk of error (score 1-3)	1.4 (0.3)	1.4 (0.3)	0.77	-0.1 (0.2)	-0.1 (0.3)	0.29
Participants with						
pre-test score ≥ 9 [1)]	n=85	n=76		n=85	n=76	
Test score (score 0-14)	11.9 (1.8)	12.2 (1.9)	0.29	0.5 (1.6)	0.4 (1.8)	0.74
Certainty (score 0-3)	2.3 (0.5)	2.2 (0.7)	0.18	0.2 (0.6)	0.3 (0.7)	0.73
Risk of error (score 1-3)	1.3 (0.3)	1.4 (0.3)	0.61	-0.1 (0.2)	-0.1 (0.3)	0.92
pre-test score < 9 [1)]	n=7	n=15		n=7	n=15	
Test score (score 0-14)	8.4 (0.3)	10.7 (2.2)	0.01	0.7 (1.3)	3.6 (1.8)	0.001
Certainty (score 0-3)	1.9 (0.5)	2.0 (0.5)	0.74	0.2 (0.7)	0.4 (0.4)	0.40
Risk of error (score 1-3)	1,7 (0.2)	1.5 (0.2)	0.03	-0.1 (0.2)	-0.3 (0.3)	0.04

Results are given as mean (SD)
[1)] Auxiliary sub group analysis
Statistical test: Mann-Withney U-test

An analysis of the main results from the 141 participants who completed the study according to protocol, generally showed the same as the intention to treat analysis, with no difference between the two didactic methods. The overall knowledge score improved from 11.1 (2.0) to 12.0 (2.0) ($p<0.001$).

Table 3 gives the results as proportion of correct answers and the proportion of answers with a high risk of error within each calculation topic before and after course. The test results in each topic for the two didactic methods showed that the classroom group scored significantly better after course in conversion of units: 86 % correct answers vs. 78 %, $p<0.001$, with no difference in the other topics. Overall, there were significant differences between the four topics in knowledge and risk of error both before and after course, $p<0.001$ (Friedman's test). Sense of coping or self esteem/well-being was not affected by the course for neither of the groups, data not shown.

Table 3 Knowledge and high risk of error within each calculation topic before and after course

	Proportion of correct answers (n=183)	Proportion of answers with a high risk of error (score=3) (n=183)

Topic (number of questions)	Before course	After course	P-value	Before course	After course	P-value
Conversion of Units (7)	73.9(20.2)	81.8(18.9)	<0.001	10.6(14.6)	10.6(14.7)	0.93
Dose-quantity-strength(4)	84.7(16.9)	87.2(17.2)	0.06	3.0 (8.2)	5.0 (11.1)	0.02
Infusions (2)	83.5(27.8)	84.4(26.0)	0.70	4.0(16.1)	4.0 (15.6)	0.87
Dilutions (1)	81.4(39.0)	84.7(36.1)	0.32	6.0(23.8)	5.0 (22.8)	0.80
In total (14)	78.9(14.3)	83.9(14.5)	<0.001	7.1 (9.6)	7.7 (9.6)	0.51

Results are given as mean (SD).
Statistical test: Wilcoxon signed rank test, Friedman's test

Factors significantly associated with good learning outcome and reduction in the risk of error after course is given in **Table 4.** Among these factors, the randomization to classroom teaching was significantly better in learning outcome, adjusted for other variables. Both low pre-test knowledge and certainty score were associated with reduced risk of error after course, as were being a man and working in hospital. Self-evaluations of coping and self esteem/well-being were neither associated with learning outcome nor risk of error. The total R^2 change for the variables significantly associated with good learning outcome and risk of error were 0.28 and 0.18, respectively.

Table 4 Factors significantly associated with learning outcome and reduction in risk of error after course in drug dose calculation

	Learning outcome		Reduction in risk of error	
	Beta	***P-value***	***Beta***	***P-value***
Sex (man)			0.20	0.006
Working in hospital	0.21	0.02	0.26	0.005
Pre-test knowledge score	-0.61	<0.001	-0.29	0.001
Pre-test certainty score			-0.25	0.003
Randomization – classroom	0.16	0.02		
Motivation for course	0.17	0.02		

Multivariable regression analysis with all participant characteristics included as possible factors (n=183).
Statistical test: Linear regression analysis, after bivariable correlation tests Pearson and Spearman

Course evaluation

Nearly all (97.5 %) of the participants stated a need for training courses in drug dose calculation. The evaluation after the course showed no difference between the didactic methods in expressed degree of difficulty or course satisfaction, data not shown. ~~Time used for self-studying was median 3-6 hours for the e-learning and 0-3 hours for the classroom group (classroom session not included),~~

p<0.001. The time used was not associated with the learning outcome. Adjusted for time for learning the randomization was no longer significantly associated with learning outcome, data not shown. The specific value of the course for working situation was scored 3.1 (0.7) in the e-learning group and 2.7 (0.7) in the classroom group (p<0.001).

Auxiliary analyses

A posthoc analysis for sub groups with pre-test knowledge score ≥ 9 and <9 is given in the lower part of **table 2**. For the participants with low pre-score, classroom teaching gave significantly better learning outcome and reduced risk of error after course. The overall knowledge score improved in the high score group from 11.6 (1.4) to 12.0 (1.9) and in the low score group from 7.2 (1.0) to 9.9 (2.3), and the difference in learning outcome was highly significant (p<0.001).

DISCUSSION

Drug dose calculation skills

The study was not able to demonstrate an overall difference in learning outcome between the two didactic methods, neither of statistical nor clinical importance. Both methods resulted in improvement of drug dose calculations after course, although the learning outcome was smaller than what was defined as clinically relevant. Adjusted for other contributing factors for learning outcome in the multivariable analysis, the classroom method was statistically superior to e-learning, and so was the case for a sub group with low pre-test result. This finding from the post hoc analysis was probably the only outcome that could have a meaningful practical implication for choice of learning strategy, if reproduced in new studies. These results were in accordance with a meta-analysis of 201 trials comparing e-learning with other methods.(19) The review summarized that any educational action gives positive outcome, regardless of method. E-learning works compared to no intervention, but tested against conventional methods it is difficult to detect any differences.

Drug dose calculations are not advanced in a mathematical sense. The basic arithmetic functions of addition, subtraction, multiplication or division are needed to decide decimals and fractions. What seems to be challenging is to conceptually understand the difference in information from the concentration denomination: percent or mass per unit volume, or the ability to set up the right calculation for the relationship between dose or mass, volume or amount and concentration or strength. A standard labelling to mass per unit volume has been strongly recommended.(20, 21)

The fact that only one out of ten nurses performed a faultless pre-test was not surprising, from what is previously shown. In a study by McMullan only 5 % of the nurses achieved 80 % correct calculations.(22) Although statistically significant, the limited overall learning outcome after the courses was somewhat disappointing, with only two out of ten with faultless tests. It seemed that the incorrect calculations were more frequent in conversion of units, the least complex task in mathematical sense. The conversion of units improved the most after course, while the learning outcome in the arithmetic tasks of infusions and dilutions were unchanged. This has also been observed by other investigators, and support the view that the challenges in drug dose calculation is more likely due to poor conceptual understanding.(10) addressesRecent papers address the importance of including both conceptual, (understanding the problem), calculation (dosage computation) and technical measurement (dosage measurement) competence in teaching nurses in vocational mathematics, with models to help them understand the" what", the" why" and the "how" in dosage problem-solving. (23, 24)

Risk of error

The study was not able to demonstrate any difference in the risk of error between the e-learning and classroom groups, neither before nor after course. Asking for certainty in each calculation made it possible for the nurses to express whether they normally would have consulted others or not when doing the calculation. Being certain that an incorrect answer was correct, was regarded as an adequate estimate for high risk of error, and tTo our knowledge, such method for estimating a risk of error from a test situation is not described by others, and may be a contribution to future research. .Due to the low learning outcome, one could fear that increased certainty would lead to increased risk of error. Therefore, it was satisfying that the overall risk of error declined after course with both methods. Although a proportion of 22 % with increased risk of error after taking the course seemed alarming, it was within the limit of what could occur by chance, due to the small learning outcome. However, one may speculate if an increased risk may be due to some participants felt safer, but not obtained increased knowledge. This might have implications for the need of follow-up after courses.

The factors that were associated with reduced risk of error after the calculation course could indicate who might benefit from training like this: being a man; working in hospital; low pre-test score; and low pre-test certainty score. This supports the finding in the auxiliary analysis; that nurses with weak drug dose calculation skills benefit most from taking courses. Nevertheless, the risk of error demonstrated in the study did not necessarily reflect the real risk of adverse event affecting patients, as the test situation cannot measure how often miscalculations were performed or how serious the clinical implications might be for any patient. Such studies still need to be done.

Importance for practice

The fact that 48 % of the participants in the study performed drug dose calculations at least weekly was more than anticipated. It has been a common perception that the need for most nurses to calculate drug doses is small in today's clinical practice. The reported extent of calculations underscores the importance of good skills in this field.

When the need for continuous improvement and maintenance of skills are identified, the time and resources available will be decisive for the possibility to implement further training activities. E-learning is more often a preferred choice in health services institutions, as it is both flexible and cost effective. In oOur study the e-learning group stated a higher specific value of the course for working situation, although the course content was similar in both methods. confirms less time consumption by e-learning, bBut this method also had more dropouts and lesser learning outcome for those with low skills. In a review article commenting upon the results of a meta-analysis of e-learning and conventional instruction methods, Cook claims that rather than more comparative studies, further research should focus on under which conditions ("how and when") e-learning is a preferable method.(12)

An implication of the findings can be to let nurses regularly perform an e-learning course followed by a screening test to uncover the weak calculation topics. Those who need further training should be offered a more tailored follow-up. Others have also documented that a combination of different learning and teaching strategies do result in better retention of drug calculation skills compared to lectures alone.(23) Further studies of the effect of the introduction of drug dose calculation apps would also be of interest, as well as more authenthic observation studies in high fidelity simulation environment, as reported from a Scottish HHS study. situations. (26).

Interestingly, the e-learning group stated a higher specific value of the course for working situation, although the course content was similar in both methods. This may be explained by the flexibility of the e-learning course, allowing the participants to concentrate on the items that were considered difficult and relevant for their work, while the classroom group had to follow through the whole programme. Nearly all the nurses realized themselves that they need more training in drug dose calculations, and an important factor was that motivation for course was associated with good learning outcome in the study. This indicates that the professional leadership in health institutions should facilitate and encourage the nurses to improve their skills further in drug dose calculations.

I addition to regularly training in calculations, written procedures for specific dilutions and infusions used in the wards would be of importance as a quality insurance for improved patient safety. This must be a part of the management responsibility.

Study limitations

The participants in this study were recruited through the management line, and the study population represents a limited part of the total nurse population. We assume that nurses with low calculation skills to a lesser degree would volunteer for such a study, and hence presume that the calculation skills in clinical practice would be lower than shown in this study. External validity might be an issue in studies with voluntary participation, and extrapolation of the findings of the study to all registered nurses should be performed with caution.

Some may question the quality of the course content and duration or teaching conditions of the courses, especially since the learning outcome of the courses were not convincing. However, the main aim for the study was to compare the two didactic methods. And, to ensure a fair comparison and similar content of the courses, the subject teacher who was a part of the group that developed the e-learning course, also was responsible for the classroom lectures. Since the teacher had an interest in both didactic methods, the probability for her to affect the course arrangements in favour of one of them was regarded as small. The questionnaire used was the same as nursing students were tested by, and the calculation tasks were considered to be in accordance with the tasks that were done in the nursing practice. ~~The additional questions devised for the study; the certainty score and the risk of error estimations, were not validated tools, and could be regarded as a methodological limitation.~~

Another limitation could be the controlled test conditions, without time pressure and interruptions that are often the case in a stressful work situation, which tend towards better results than in reality. On the other hand, the calculation test situation itself may be stressful for the nurses, since many have struggled to pass a similar test during their studies.

Selecting two dimensions from the GHQ30 questionnaire may also be a methodological limitation. Although no correlation between the outcomes and coping or well-being/self esteem were detected, the usage of only parts of the tool excluded the possibility of detecting an association between physiological well-being in general and drug dose calculation skills.

CONCLUSION

The study was not able to demonstrate any differences between e-learning and classroom teaching in drug dose calculation, with respect to learning outcome, certainty or risk of error. The overall learning outcome was without practical significance, and conversion of units was the only topic that was significantly improved after course. An independent factor in favour of classroom teaching was weak pre-test knowledge, while factors suggesting use of e-learning could be the need for training in relevant work specific tasks and time effective repetition.

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Competing interests

BOS, IJ and PGF: None

GKD was part of the group who developed the e-learning programme used in the study, and the course was made commercially available from autumn 2009.

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FIGURE LEGENDS

Figure 1 Participant flow chart

Figure 2 Test results in drug dose calculations

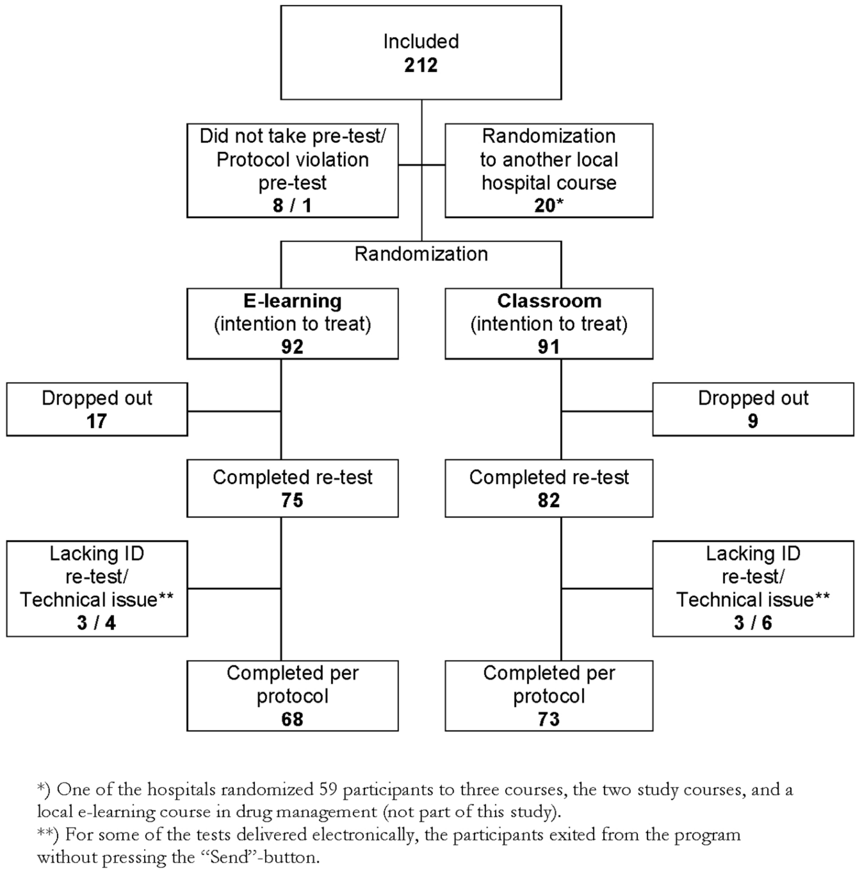

Figure 1 Participant flow chart
210x193mm (200 x 200 DPI)

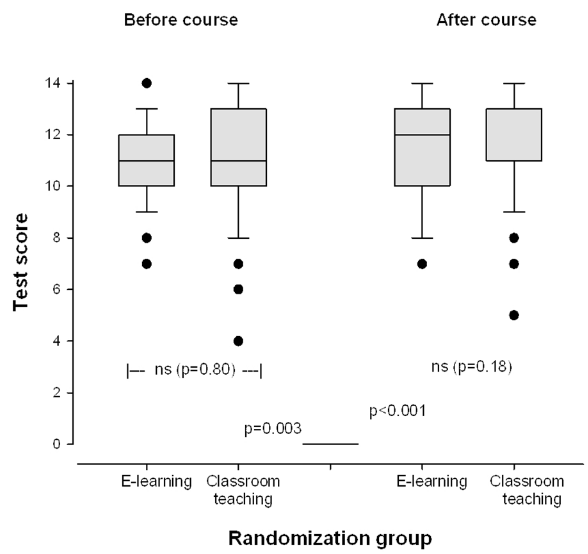

Figure 2 Test results in drug dose calculations
210x297mm (150 x 150 DPI)

For each question, the participants should tick off for one of the alternative answers and also answer the following question: "How certain are you that your answer is right – i.e. what would you do in a real situation?"
0= Very uncertain - would search for help; consulted colleagues/reference books.
1= Relatively uncertain – would probably search for help; consulted colleagues/reference books
2= Relatively certain - would probably not search for help by consulting colleagues/reference books
3= Very certain - would not search for help by consulting colleagues/reference books
NB! No answer will be recorded as 0= very uncertain

DRUG DOSE CALCULATIONS – TEST 1 BEFORE COURSE

Certainty: 0 1 2 3

1. 1 hour 3 minutes = 103 minutes
33 minutes
63 minutes
73 minute
How certain are you in this answer:

2. 20 micrograms = 0,02 mg
20000mg
0,2 mg
0,002 mg
How certain are you in this answer:

3. Potassium cloride for infusion has the concentration 1 mmol/ml. The physician has prescribed a dose of 25 mmol for infusion. How many ml of the infusion concentrate equals 25 mmol?
1 ml
250 ml
25 ml
2,5 ml
How certain are you in this answer:

4. The patient should have 10 500 IE Heparin as intervenous infusion. The concentration in the vial is 5 000 IE/ml. How many ml do you pull out from the vial?
2,1 ml
3 ml
0,5 ml
21 ml
How certain are you in this answer:

5. 2,5% = 250 mg/ml
2,5 mg/ml
0,25 mg/ml
25 mg/ml
How certain are you in this answer:

6. 250 mg/ml = 25 %
2,5 %
0,25 %
250 %
How certain are you in this answer:

7. 0,42 l = 420 ml
42 ml
0,42 ml
4200 ml

How certain are you in this answer:

8. One Marevan tablet contains 2,5 mg warfarin, og may be divided into 4 pieces. How many mg does a patient get when given 2 and ¼ tablet?

1,1 mg
1,4 mg
5,6 mg
6 mg

How certain are you in this answer:

9. You give a patient 3 and ½ tablet of a drug, and each tablet contains 5 mg. How many mg does the patient get?

1,4 mg
17,5 mg
1,75 mg
15 mg

How certain are you in this answer:

10. Doxorubicin 50 mg injection substance is diluted in 25 ml sterile water. What is the concentration of the solution?

1250 mg/ml
2 mg/ml
0,5 mg/ml
20 mg/ml

How certain are you in this answer:

11. Furadantin tablets contain 5 mg/tablet. The dosage is 3 mg/kg body weight per 24 hours, in two divided daily doses. The child's weight is 20 kg. How many tablets should the child get each time?

0,5 tablet
12 tablets
6 tablets
3 tablets

12. A patient should have 500 ml Glukose 50 mg/ml intravenously. How many ml/hour should the infusion pump be set at, if the infusion time should be 4 hours?

125 ml/hour
100 ml/hour
12,5 ml/hour
2,1 ml/hour

How certain are you in this answer:

13. A patient gets Invertose 120 mg/ml. Due to the risk of acidosis, the infusion rate must not exceed 10 mg/kg/hour. What is maximum drop rate (drops/hour) for a patient weighing 30 kg. The drop number is 20/ml.

100 drops/hour.
18 drops/hour.
60 drops/hour.
50 drops/hour.

How certain are you in this answer:

14. 20 ml Hibitane 20% should be diluted to a solution with the concentration 5 mg/ml. How many ml is the diluted solution?

780 ml
800 ml
80 ml
820 ml

How certain are you in this answer:

Certainty

DRUG DOSE CALCULATIONS – TEST 2 AFTER COURSE

0 **1** **2** **3**

1. 1 hour 3 minutes = 55 minutes
83 minutes
63 minutes
60 minutes
How certain are you in this answer:

2. 50 micrograms = 0,50 mg
0,050 mg
5,0 mg
50,0 mg
How certain are you in this answer:

3. A concentrate of mono potassium phosphate for infusion has the concentration 1 mmol/ml. The physician has prescribed a dose of 0,15 mmol/kg, to be added into an infusion liquid. The patient weigh 54 kg. How many ml of the infusion concentrate should be added to the infusion liquid?
1,5 ml
8,1 ml
0,1 ml
1 ml
How certain are you in this answer:

4. A male cancer patient should have 9 IE Bleomycin per square meter body surface once a week as an intervenous injection. His estimated body surface is 1,8 square meter. 15 IE Bleomycin (pouder) are dissolved in 10 ml injection liquid. How many ml do you use from the solution to give him a correct dose?
10,8 ml
10,0 ml
9,0 ml
16,2 ml
How certain are you in this answer:

5. 0,1 % = 0,01 mg/ml
0,10 mg/ml
1,0 mg/ml
10 mg/ml
How certain are you in this answer:

6. 100 mg/ml = 0,1 %
1,0 %
10 %
100 %
How certain are you in this answer:

7. 0,42 l = 4,2 ml
42 ml
420 ml
4200 ml
How certain are you in this answer:

	Certainty			
	0	1	2	3

8. Phenergan injection fluid has the consentration 25 mg/ml. 1,2 ml has been pulled out from the container. What is this dose in mg?

25 mg
30 mg
20,8 mg
33 mg

How certain are you in this answer:

9. A child should have 150 mg acetylsalicylic acid. Novid contains 0,3 grams/tablet. How many tablets would you give the child?

3 tablets
2 tablets
1 tablet
0,5 tablet

How certain are you in this answer:

10. 20 ml Glyceryl nitrate 5 mg/ml concentrate for infusion is given in 500 ml glucose liquid for infusion. What is the concentration of glyceryl nitrate in the infusion liquid?

60 microgram/ml
250 microgram/ml
200 microgram/ml
100 microgram/ml

How certain are you in this answer:

11. Lanoxin mixture contains 50 micrograms digitoxin*) per ml. A child weighing 15 kg should get 0.01 mg/kg body weight per day. How many ml would you give the child per day? (*)before the change to digoxin on the market)

0,5 ml
2 ml
3 ml
4 ml

How certain are you in this answer:

12. A patient should have furosemide 2 mg per minute intravenously. 25 ml furosemide injection fluid with the concentration 10 mg/ml is added to NaCl to a total volume of 250 ml. The infusion is given by an infusion pump. How many ml per hour would you set the infusion pump to give?

125 ml/t
120 ml/t
100 ml/t
50 ml

How certain are you in this answer:

13. 2 grams of Fortum infusion substance is dissolved in 50 ml NaCl 9 mg/ml infusion liquid. The infusion is given during 40 minutes. What is the infusion rate in drops per minute. The drop number is 20/ml.

25 drops/minute
50 drops/minute
5 drops/minute
20 drops/minute

How certain are you in this answer:

14. 2 grams of Keflin injection substance (powder) is dissolved in 10 ml sterile water. What is the concentration in this solution in mg/ml?

50 mg/ml
100 mg/ml
20 mg/ml
200 mg/ml

How certain are you in this answer:

CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	1
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	2
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	3
	2b	Specific objectives or hypotheses	3
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	3
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	ns
Participants	4a	Eligibility criteria for participants	3
	4b	Settings and locations where the data were collected	3
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	4
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	5-6
	6b	Any changes to trial outcomes after the trial commenced, with reasons	na
Sample size	7a	How sample size was determined	4
	7b	When applicable, explanation of any interim analyses and stopping guidelines	na
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	4
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	No
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	4
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	na

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	4
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	6
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	9 ,11
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	18
	13b	For each group, losses and exclusions after randomisation, together with reasons	18
Recruitment	14a	Dates defining the periods of recruitment and follow-up	3
	14b	Why the trial ended or was stopped	na
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	7
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	Tables
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	Tables
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	Tables
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	9
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	na
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	14
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	13
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	11-13
Other information			
Registration	23	Registration number and name of trial registry	na
Protocol	24	Where the full trial protocol can be accessed, if available	Author
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	15

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.