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Mathematical ability of first year undergraduate paramedic students—A before and after study

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SUMMARY

Background: An ability to accurately perform drug calculations unassisted is an essential skill for all health professionals, with various occupational-specific stressors exacerbating mathematical deficiencies.
Objectives: The objective of this study was to determine the unaided mathematic ability of first year undergraduate paramedic students before and after mathematical and drug calculation tutorials.
Methods: Students were administered a questionnaire containing demographic, drug calculation and arithmetic questions during week one of the semester before the tutorials. During the semester students participated in three 2-hour tutorials which included both mathematical and drug calculation questions without assistance of computational devices. At the end of semester was a summative drug calculation examination of which five key questions were compared to similar questions from the first questionnaire. Descriptive statistics describe the demographic data with a paired t-test comparing the questionnaire and exam results.
Results: Drug calculation and mathematical ability was markedly improved following the tutorials, mean score of correct answers before 1.74 (SD 1.4) and after 4.14 (SD 0.93), $p < 0001$. When comparing the correct results for the same question type, there were statistically significant differences in four of five different drug calculations: volume of drug drawn up 10 v 57 $p < 0.0001$, infusion rate 29 v 31 $p = 0.717$, drip rate 16 v 54 $p < 0.0001$, volume from a syringe 30 v 59 $p < 0.0001$, and drug dose 42 v 62 $p < 0.0001$. Total errors reduced from 188 to 45.
Conclusions: First year undergraduate paramedic students initially demonstrated a poor ability to complete mathematical and drug calculations without the assistance of computational devices. This improved significantly following appropriate education and practice. Further research is required to determine the retention of this ability over time.

Introduction

Mathematical ability and numeracy skills are fundamental requirements for health care professionals undertaking patient management and treatment (Rothman et al., 2008). Paramedics are required to calculate and administer drugs based on various factors, such as a patient's age, weight, and vital signs. Studies have reported poor drug calculation abilities by both undergraduate and qualified paramedics, and yet only one university in Victoria, Australia has mathematics as a prerequisite (Australian Catholic University, 2015; Ballarat University, 2015; Bernius, 2008; Eastwood et al., 2012; Hubble, 2000; Latrobe University, 2015; LeBlanc, 2005; Monash University, 2015; Victoria University, 2015).

Health care professionals face a number of common stressors and factors that can impede their ability to perform drug calculations, such as stress, fatigue, skills decay and distractions (Deans, 2005; Preston, 2004; Trim, 2004; Wright, 2006). Paramedics face additional unique factors in the out-of-hospital environment such as distractions caused by bystanders, loud noise, poor lighting, variation in resources being used and fewer safeguards generally found in the hospital or health service environment (LeBlanc, 2005).

Drug errors have a significant impact on patient health outcomes and medical costs. Medication-related errors in Australia cost an estimated at $660 million annually (Roughead and Semple, 2009). Similarly in the UK, a report on the adverse events of the National Health Service found that 25% of all litigation claims in general medical practice were due to medication errors (Department of Health, 2000). In 2008 medication errors occurred in the US in 7.1 million inpatient and outpatient visits costing approximately $21 billion (Massachusetts Technology Collaborative (MTC) and NEHI, 2008; National Priorities Partnership and National Quality Forum, 2010). Despite the international literature, the rate of medication-related medical errors in the setting of out-of-hospital paramedic practice is unknown (Eastwood et al., 2009).

Alarmingly, previous research into nurses and undergraduate paramedics has found that conceptual errors, the inability to formulate an equation, make up the majority of all errors, followed by arithmetical errors, the inability to operate an equation, and computational errors, basic errors of addition, subtraction, multiplication and division (Blais and Bath, 1992; Eastwood et al., 2009, 2011). The fact that the errors

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are conceptual means that they are not simply random errors that may occur when one is distracted, they demonstrate a fundamental lack of understanding and by their very nature will occur every time a calculation is attempted. For this reason, a basic lack of mathematical comprehension must be addressed early in the education setting. Several studies involving undergraduate nursing students have seen some success in further mathematical education classes to improve the students' mathematical knowledge (Rice and Bell, 2005; Sredl, 2006; Starkings, 2003). While there was improvement it was often still well short of what would be considered clinically safe. However, one study has shown that the type of error shifts away from conceptual errors (Rice and Bell, 2005). There is also evidence that a simple 1 hour tutorial is not enough to rectify the problem (Maag, 2004).

Undergraduate paramedic students have never been investigated for the effects of a mathematical program, in terms of any improvement in understanding, and for a shift in error type. The objective of this study was to determine the unaided mathematic ability of first year undergraduate paramedic students before and after a mathematical and drug calculation program. The errors were evaluated to determine the category of error, as well as the percentage of error reduction. We also evaluated the education to determine whether it successfully reduced higher order error types.

Method

Design

This study used a cross-sectional quasi-experimental approach with a pre- and post-test study design using a paper-based questionnaire to elicit responses to a variety of mathematical and drug calculation questions.

Participants

Students enrolled in the first year pharmacology subject of the Bachelor of Emergency Health (Paramedic) (BEH) at Monash University were eligible to participate in the study. There were no exclusion criteria. There were 73 students eligible to participate in the study.

The pre-test participants consisted of a convenience sample of students recruited prior to the first mathematical tutorial.

Drug Calculation and Mathematical Instruction

The students undertook three basic mathematical and drug calculation tutorials that were new to the student curriculum. They were incorporated into a new pharmacology subject in the first year of the three-year undergraduate degree. As these tutorials formed part of the curriculum, they were compulsory for all students. Wright (2005) reported a three-stage process in delivering mathematics education. Wright (2005) suggested firstly teaching the mathematical concepts, then the formulae and finally allowing for the application of these skills in a clinical setting. We modified this approach by firstly delivering the basic mathematical concepts, followed by two separate tutorials on the formulae with the clinical application of these formulae occurring in the latter half of the respective tutorials.

The first 2 hour tutorial included:

- multiplication and division by factors of 10, 100 and 1000;
- conversion of fractions to decimals;
- converting units of measure;
- multiplication of whole numbers and decimals, and
- simplifying fractions.

The second 2 hour tutorial covered:

- drug dosage calculations;
- volume dosage calculations;
- application of these formulae to practice situations.

The third and final 2 hour tutorial covered: fluid dosage and rate calculations

- revision of dose and volume calculations
- application of these formulae to practice situations.

Instrumentation

The pre-test was a previously used paper-based questionnaire consisting of a series of demographic, drug calculation, and mathematical questions. The drug calculations used a medical focus to give the students a sense of relevance to their current curriculum and future clinical practice. The mathematical questions contained standard calculations and conversions, e.g. convert a fraction to a decimal. There were twelve drug calculations and mathematical questions in total and students were allowed 30 min to complete it.

The drug calculation questions covered the volume of drug drawn up in a syringe, a drip infusion rate in milliliters per hour, the number of drops per minute for an infusion, the volume of a drug in milliliters from a syringe, and the drug dose in milligrams. There was one type of each question in the before and after sections of the study for ease of comparison.

The post-test questions were an extraction of data from the drug calculation questions found in the end of semester theory examination and were used for comparison with the pre-test. These questions were similar, but used different numerical values and settings to allow for comparison of the students skill, rather than a test of their memory. Five were used for comparison in this study.

Procedures

The quasi-experimental approach was used as the intervention was incorporated into the compulsory student curriculum so all students would receive the education.

A research assistant, not involved in teaching or facilitating tutorials for the students, invited first year BEH pharmacology students to participate in the study at the end of their first tutorial during the first week of the university semester. This was done to reduce the possibility of coercion. Students were provided with an explanatory statement and advised that their participation was voluntary and that they could withdraw at any stage up until the questionnaire was submitted.

In the following three weeks students were given three tutorials (one 2 hour tutorial a week) on mathematics and drug calculations in which they were not permitted to use a calculator. At the end of the 12 week semester the final examination contained a section devoted to drug calculations to be completed without the aid of a calculator, and these were used to compare with the pre-test. The questionnaire and tutorials were run in March 2011. The post-test data was collected in June 2011.

The pre-test was graded and the errors were categorized into computational, arithmetical and conceptual categories for further analysis. The post-test was graded by their subject coordinator, then de-identified and forwarded to a research assistant for error classification. Individual results were not matched between the two questionnaires.

Data Analysis

Data were analyzed using SPSS (Statistical Package for the Social Sciences Version 20.0.0.2, IBM Corporation, Armonk, New York, USA). Descriptive statistics, medians, means and standard deviation (SD) and ranges were used to describe the demographic data and some of the drug calculation data with a paired t-test used to compare the pre and post-test results. Proportions were used to compare the differences between each error type in the before and after results. All tests were two tailed unless otherwise stated with results considered statistically significant if the p value was <0.05. All confidence intervals (CI) are 95%.