Original Article

Undergraduate paramedic students cannot do drug calculations

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BACKGROUND: Previous investigation of drug calculation skills of qualified paramedics has highlighted poor mathematical ability with no published studies having been undertaken on undergraduate paramedics. There are three major error classifications. Conceptual errors involve an inability to formulate an equation from information given, arithmetical errors involve an inability to operate a given equation, and finally computation errors are simple errors of addition, subtraction, division and multiplication. The objective of this study was to determine if undergraduate paramedics at a large Australia university could accurately perform common drug calculations and basic mathematical equations normally required in the workplace.

METHODS: A cross-sectional study methodology using a paper-based questionnaire was administered to undergraduate paramedic students to collect demographical data, student attitudes regarding their drug calculation performance, and answers to a series of basic mathematical and drug calculation questions. Ethics approval was granted.

RESULTS: The mean score of correct answers was 39.5% with one student scoring 100%, 3.3% of students ($n=3$) scoring greater than 90%, and 63% ($n=58$) scoring 50% or less, despite 62% ($n=57$) of the students stating they 'did not have any drug calculations issues'. On average those who completed a minimum of year 12 Specialist Maths achieved scores over 50%. Conceptual errors made up 48.5%, arithmetical 31.1% and computational 17.4%.

CONCLUSIONS: This study suggests undergraduate paramedics have deficiencies in performing accurate calculations, with conceptual errors indicating a fundamental lack of mathematical understanding. The results suggest an unacceptable level of mathematical competence to practice safely in the unpredictable prehospital environment.

KEY WORDS: Emergency medical technician; Education; Medication errors; Safety management

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INTRODUCTION

Mathematical calculations are a fundamental component of paramedic practice utilised in areas of care such as weight, equipment size and drug dosage calculations. When paramedics administer drugs to patients it is assumed their drug dosage calculation are always 100% accurate. Inaccuracy can result in compromised patient safety, potentially leading to underdosing, overdosing, adverse complications, or at worse, death.

Professional credibility between health care professionals and continuity of patient care could be jeopardised if the drug calculations cannot be fully explained and understood during interactions such as handover in the emergency department. Currently no evidence can be found regarding the cost of drug dosage miscalculations in the pre-hospital setting, however medication-related errors cost approximately \$380 million in the public hospital system annually and account for up to 20% of all health-care errors in Australia.^[1]

Current literature has revealed an alarmingly low level of accuracy when performing unaided mathematical calculations amongst three cohorts of qualified practicing paramedics in the United States and Canada.^[2-4] Results from the studies varied with mean scores ranging from 39.8% to 65% accuracy.^[2-4] Studies^[3-10] from many medical disciplines investigating mathematical competence suggest issues such as skills decay, the presence of equipment that automatically performs the calculations, length of time in the job, poor mathematical education during primary and secondary schooling, and pressures associated with caring for the patient during high-pressure or stressful situations as possible reasons for poor calculation performance.

Various studies have categorised mathematical errors and three distinct groups have emerged. Conceptual errors are the most common type of error, and involve the inability to formulate the mathematical question correctly from the information given. Arithmetical errors form the second group and occur when a person is unable to operate an equation correctly. The final type is computational errors involve miscalculation of simple functions such as multiplication, division, subtraction or addition.^[9-14]

In Victoria, Australia, the final two years of secondary schooling form the graduation requisites of the Victorian Certificate of Education (VCE). During the VCE there are three levels of mathematics in each of the final two years of secondary schooling. In year 11 this ranges in an increasing order of difficulty: foundation maths, general maths and finally maths methods. In year 12 this ranges from again in an increasing order of difficulty: further maths, maths methods and finally specialist maths.^[15]

There is a variation in mathematical prerequisites between the undergraduate paramedic courses at Victorian universities due to non-standardization and non-accredited coursework programs. Some courses do not require any mathematics at all during year 12 and others require any maths during year 12.^[16-18]

The objective of this study was to determine if undergraduate paramedics at a large Australia university could accurately perform common drug calculations and basic mathematical equations normally required in the workplace.

METHODS

Study design

A cross-sectional study methodology using a paper-based questionnaire was administered to undergraduate

paramedic students to collect demographical data, student attitudes regarding their drug calculation performance, and answers to a series of basic mathematical and drug calculation questions.

Participants

One hundred and seventy-six undergraduate paramedics enrolled in the Bachelor of Emergency Health (Paramedic) were eligible to participate in the study. Forty-two students were enrolled in the first year, 61 students enrolled in the second year and 73 students enrolled in the third year. Only those who met the inclusion criteria of being a student enrolled in the above course were invited to participate in the study. There were no exclusion criteria.

Instrument

A paper-based questionnaire consisting of a series of demographic, drug calculation, and mathematical questions. There were three sections within the questionnaire collecting demographical data, information identifying factors students believe to be inhibiting their mathematical performance, and finally a series of 12 questions consisting of various drug calculations and mathematical equations. The written problems used a medical focus in order to give the students a sense of relevance to their current curriculum. Several undergraduate paramedic course unit co-ordinators reviewed the questionnaire prior to its implementation for its face and content validity. It was also piloted on a group of qualified paramedics. Changes were made to the questionnaire based upon the feedback obtained.

Procedures

No notice was given before recruitment to avoid any students studying prior to seeing the questionnaire. An explanatory statement was supplied to highlight the research question, aims of the study, and issues such as confidentiality and recruitment. The questionnaire was administered early in the first semester of the year, at the end of a lecture by a non-teaching member of the staff. Students were not permitted to use a calculator but were advised to use the questionnaire form to do their works. First and second year students, who had not yet completed education on drug calculations as part of their course were given a sheet with the relevant formulae. It should be noted that the formulae were not essential for the calculations to be conducted. The students were not given a set time to complete the questionnaire, and it

aimed to see if the students could successfully complete the required calculations.

The numbers of correct, incorrect, and 'not attempted' answers were summated, and errors were divided into conceptual, arithmetical or computational categories where possible based on the works. 'Not attempted' questions formed their own category and were not included in the incorrect category. Fifty percent was used as the pass mark; however results were also grouped according to a 90% mastery level. The results were compared to the other international literature. The results were also analysed to find their relation to the demographical data collected.

Data analysis

Data were analysed using SPSS (Statistical Package for the Social Sciences Version 18.0, SPSS Inc., Chicago, Illinois, USA). Descriptive statistics were used to describe the demographic data and some of the drug calculation data.

RESULTS

Ninety-two of 176 students participated in the study, with a 52.3% response rate. Twenty-two students were from the first year (52%), 15 from the second year (24%) and 55 from the final year (75%) of the course. The majority of the students, 73% ($n=67$) were less than 26 years of age and most of them (60%) were female.

Ninety-eight percent students ($n=90$) had completed a minimum of year 12 or equivalent level of education. Most of the students, 78% ($n=72$) either had a gap year, were returning to study or undertook another course prior to entry into the paramedic course rather than entering directly from secondary education. Nearly two-thirds of the students or 64% ($n=59$) had participated in other tertiary education prior to their current course. Only 5.4% ($n=5$) of the students had less than year 12 level of mathematical education (Table 1).

Table 2 shows that there was a notable difference in performance amongst the various maths education levels. The only two mathematic cohorts to achieve means scores above the 50% pass mark were the 19.6% ($n=18$) of students who had completed either the highest level of VCE mathematics, specialist maths, or mathematics at a tertiary level of education. However they barely achieved this with scores of 54.2% and 53.6% respectively (and a combined average score of 53.7%). It can be seen in all groups except the 'Tertiary Level Maths' and the 'Other' category, that the main type of error was conceptual in nature.

Sixty-two percent ($n=57$) of the students indicated they did not have any issues with drug calculations; however paradoxically the same number believed that infrequent exposure to mathematics may be inhibiting their calculation abilities. Seventy-five percent ($n=69$) of the students believed that their secondary mathematics education was adequate, with 53% ($n=49$) believing their tertiary mathematics education was adequate.

The undergraduate paramedics achieved an overall mean score of 39.5%. Nearly a quarter of the questions (23.9%) were answered incorrectly and just over one third (36.6%) of them were not attempted at all. Most of the errors were conceptual in nature with 48.5% of all errors falling into this category. The arithmetical errors made up 31.1%, while the computational errors made up 17.4% of all of the errors. Three percent of the incorrect

Table 1. Students' highest level of maths education

Maths level	<i>n</i> (%)
High school maths (<yr 12)	5 (5.4)
Other (including interstate maths education)	7 (7.6)
HSC maths	6 (6.5)
VCE further maths	18 (19.6)
VCE maths methods	38 (41.3)
VCE specialist maths	4 (4.4)
Tertiary level maths	14 (15.2)
Total	92 (100)

Table 2. Average scores for each maths level of education and types of errors

Highest level of school maths	Average score %	% of errors			
		Conceptual	Arithmetical	Computational	Unable to determine
Other (interstate maths education)	23.8	38.1	47.6	9.5	4.8
High school maths (<yr 12)	35.0	50.0	41.7	8.3	—
HSC maths	31.9	53.6	25.0	17.9	3.6
VCE further maths	25.9	53.8	29.2	13.8	3.1
VCE maths methods	43.9	48.5	32.0	17.5	2.1
VCE specialist maths	54.2	66.7	16.7	16.7	—
Tertiary level maths	53.6	31.0	24.1	37.9	6.9

answers could not be categorised because of lack of information. Only one student achieved 100% accuracy and 3.3% ($n=3$) of the students achieved scores of 90% or greater. Nearly two thirds of the students, 63%, ($n=58$) failed to achieve scores of 50% or better.

When comparing the three year levels of the paramedic course, it was found that the first and second year students who had not yet completed their vocation focused maths education, and had a formulae sheet achieved scores of 53.4% and 57.8% respectively. The final year level of the course achieved an average score of 28.9%. The third year students were not supplied with the formulae sheet as this information should have been part of their current knowledge. It should also be noted that the formulae sheets were not necessary to complete the problems, but their presence made the calculation faster. The third year students also had the largest number of 'not attempted' questions with 53% of the total number of questions left unattempted. We believe this high 'not attempted' rate is due to the students' inability to recall the appropriate formula, hence the answer area was left blank.

The 21.7% ($n=20$) of the students who entered directly from the secondary school got an average score of 44.6%. A gap year was taken by 10.9% ($n=10$) of the students who had an average score of 38.3% and 67.4% ($n=62$) who did not enter either directly from the secondary school or after a gap year and achieved an average score of 38.0%. When the students who entered directly from the secondary school were stratified into their various highest levels of maths education it was found that only the school-leavers who completed specialist maths passed the questionnaire with an average mean score of 70.8%. Of the students who had a gap year prior to entry into the course, only those who completed specialist maths and maths methods achieved average mean scores of 66.7% and 50%, respectively. The students who had completed some tertiary levels of mathematics in the group that had not entered directly from the secondary school and had not had a gap year prior to entry were the only students to pass in this cohort with a score of 53.6%.

DISCUSSION

To our knowledge this is the first study internationally to investigate the mathematical competence of undergraduate paramedic students. Deficiencies were identified and the conceptual nature of most errors indicated that there is an insufficient level of

understanding of basic mathematical principles. This was demonstrated by many students' inability to extract the required data from the information given to formulate a mathematical equation and then calculate a correct answer.

The overall mean score was 39.5% with only one student achieving 100% accuracy, 63% ($n=58$) failed to achieve scores of 50% or better, and only three students (3.3%) achieved scores of 90% or greater. These results are not unlike those produced in previous international studies in practicing paramedic mathematical performance where average scores of 39.8% to 65% were reported.^[2-4]

Despite the fact that some Victorian undergraduate paramedic courses do not require year 12 mathematics, 94.6% ($n=87$) of the students had completed at least year 12 mathematics. It was found on average that only students who had completed VCE specialist maths (the upper tier of secondary mathematical education in Victoria, Australia) or tertiary level mathematics, which consisted of 19.6% ($n=18$) of the students, passed the questionnaire with scores ranging from 53.6% to 54.2%. Whilst this questionnaire only required a lower to middle secondary school level of mathematic knowledge, one can only speculate that these students may have had a sound mathematical knowledge in order to successfully complete these upper tier subjects and this translated into the pass marks achieved in this study. It can also be speculated that of the students who did not enter the course directly from the secondary school and those students who completed tertiary level mathematics had not had as much time pass since last being exposed to mathematic skills.

The results from this study suggest that there may have been an element of knowledge decay. In the two groups that had the smallest amount of time pass since secondary education, being 'directly from secondary education' and 'after a gap year', those students who completed specialist maths averaged scores of 70.8% and 66.7% respectively. Students in the group that did not enter 'directly from secondary education' or 'after a gap year' only passed if they had completed a tertiary level of mathematics education since leaving secondary school, averaging a score of 53.6%. This tertiary education may have been sufficient to re-engage the students in the basic mathematical principles required. We can only speculate that perhaps due to processes such as knowledge decay, any prolonged amount of time without mathematical calculation exposure can result in a deterioration in performance.^[2,3,5-10] Without further qualitative feedback

from the students, the reasons behind such poor performance are unclear.

Interestingly 62% ($n=57$) of students believed that they did not have any drug calculation issues, which is supported by the results found in the study by Hubble et al^[3] where 63.5% of the practising qualified paramedics in the United States who participated in a survey believed that drug calculations were 'not stressful at all'. Our study also supports the finding by Hubble et al^[3] that there was no correlation between actual skill level and self-rating comfort levels.

Conceptual errors were the most common type of errors that occurred (48.5%) supporting much of the literature relating to paramedic and nursing mathematic performance which also found conceptual errors to be the most common.^[3,9,11] This result indicates that in nearly half of all the errors that occurred, students were unable to extract the relevant data from the question to formulate any type of mathematical equation in order to solve the problem. The arithmetical errors were also alarming with 31.1% of all errors demonstrating that students were unable to operate the equation they had formulated from given information or that was presented to them.

Computational errors made up 17.4% of all the errors. These were basic errors of addition, subtraction, multiplication or division. These errors may have been addressed by the use of calculators; however the levels of conceptual and arithmetical errors indicate that in many mathematical operations, the students would not have been able to use a calculator appropriately, as they would either not have been able to extract the relevant information or not been able to input the given information in the correct format into the calculator.^[19-21]

It is expected that in all settings there will be some small degree of human error in the form of computational errors. However it would be almost impossible for a health professional demonstrating the level of mathematical competence found in this study to detect such errors. The inability to identify an error has been documented in the literature and has been replicated within this study with students not identifying their unreasonable answers as perhaps being incorrect, therefore highlighting a lack of conceptual understanding.^[12]

These results were produced in a classroom environment with all of the situational stressors of a real time patient care setting removed. When considering these results alongside the results produced in previous studies, calculation and drug administration error is not only real but likely to occur in approximately half of

all dosage calculations, thereby potentially putting the patient at risk.^[3,4,14,22] The potential costs to the employer associated with litigation and re-education of the staff are significant without considering the costs of the ongoing management for a poorly managed patient, or the overall cost associated with potential/actual patient harm.

The poor performance highlighted in this study has identified a need for greater mathematics education during the undergraduate paramedic course and the possible need for higher mathematics pre-requisites for entry into undergraduate paramedic courses.

Further research needs to be undertaken to determine whether there are more issues surrounding the students' poor performance. Evaluation of whether the fundamental mathematic principles are being understood at the secondary school level may need to occur. Tools such as pre-formulated charts and calculators should also be evaluated for their effectiveness to determine whether these can improve performance. However one should remember that these tools are not always available, particularly within the pre-hospital environment. Finally, the ambulance services and the broader health care services sector within Australia need to evaluate their existing workforces' current level of mathematic ability to determine whether there are similar numeracy issues and whether mathematics education needs to be extended into these areas as well.

Findings from this study have previously been released to the Victorian ambulance service, Ambulance Victoria, and academic staff within the department. The findings from this study have led to a math pre-requisite being added to the entry requirements for students entering into the Bachelor of Emergency Health (Paramedic) course at Monash University. Ambulance Victoria has added a drug calculation assessment as part of the entry requirements for university graduates because of this study and findings during internal clinical audit.

This study is potentially limited as it was undertaken at one university with a small sample of students and was conducted in the classroom environment, thereby limiting the generalisability of the findings to clinical practice. The first and second year students had not yet had their drug calculation education as part of their curriculum which may have affected their performance. However the required formulae were based on basic mathematical principles the students were taught early during their secondary education and were provided with the questionnaire.

In conclusion, in a non-stressful classroom situation

this study suggests that many students are incapable of performing basic mathematical and drug calculations. They are also unable to extract the relevant information in order to formulate an equation. The findings from this study largely support the literature about qualified paramedic drug calculation abilities, by demonstrating a significant lack of accuracy when conducting drug calculations with the most frequent type of errors being conceptual in nature. Undergraduate paramedic courses should consider reviewing the mathematical prerequisites for entry and incorporate further mathematical education into their curriculum.

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