Research

Determining the ability of paramedic students to do drug calculations

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Abstract

Introduction

Mathematical ability and numeracy skills are fundamental requirements for healthcare professionals undertaking patient management in a range of healthcare settings. The objective of this study was to ascertain the mathematical and drug calculation ability of undergraduate paramedic students at an Australian university in the state of Queensland.

Methods

This study utilised a cross-sectional study design with a previously used paper-based questionnaire to elicit responses about a range of mathematical calculations. A total of 185 Bachelor of Paramedicine students were eligible for this study. The drug calculations were provided using common pre-hospital management scenarios plus additional basic mathematical calculations. Students had no knowledge of the study before receiving the questionnaire at the end of a lecture. Descriptive and inferential statistics were used to report on demographic information and comparisons.

Results

There were 139 (75.1%) students who participated. Females comprised 59% of the total students with most students less than 25 years of age. Three (2.2%) students answered all questions correctly, however 75 (54.0%) students scored 50% or less. There were 102 (73.4%) conceptual errors, 111 (79.9%) arithmetical errors, and 29 (20.9%) computational errors. There was no statistically significant difference between females and males for the total of correct answers or the types of calculation errors.

Conclusion

Results from this study demonstrate that paramedic students from an Australian university struggle to solve basic mathematical calculations unaided in a classroom environment. Universities need to ensure mathematical capability with mastery testing, so they are safe when administering drugs on entering the workforce.

Keywords:

emergency medical technicians; ambulance; paramedic; education; calculations; mathematics

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Introduction

Mathematical ability and numeracy skills are fundamental requirements for healthcare professionals undertaking patient assessment and management in a variety of healthcare settings. There is a community expectation that healthcare professionals will conduct drug calculations with complete accuracy. However, previous research has identified many undergraduate and qualified healthcare professionals, including nurses and paramedics, are unable to conduct basic mathematical operations sufficiently to achieve 50% or higher in classroom-based tests (1-6).

Drug errors have a significant impact on patient health outcomes and medical costs. Medication-related errors in Australia cost an estimated \$1.2 billion annually and over \$4 billion annually in the United States (4,5). To date, limited research has been conducted in Australia on the performance of undergraduate paramedic students. With the ever-expanding skillsets of Australian paramedics, including a broader range of pharmacological interventions and the need to ensure accurate interventions for patients, the need to ensure patient safety with medication administration is paramount.

Particular paramedic interventions such as drug administration, paediatric defibrillation, endotracheal tube and laryngeal mask sizing and fluid resuscitation volumes utilise mathematical computations based on a patient's age, weight or vital signs. To reduce the cognitive load during stressful situations, paramedics have transitioned to using mathematical aids such as calculators and smart phone applications. However, it is important to note that those support systems are sometimes unavailable or fail. Given the dynamic and time sensitive environment in which paramedics operate, when the systems are unavailable or fail during a patient encounter, the paramedic on-scene must possess the ability to conduct the calculations manually. Moreover, all healthcare professionals should be able to recognise when a calculated drug dose 'appears' incorrect. An example of this involves a common error whereby drug calculations are incorrect by a factor of 10. This may result in the need to draw up many vials of a drug, perhaps more than paramedics carry. This should highlight that the drug calculation needs to be checked.

Previous research into undergraduate paramedics at one university in Australia found students answered only 39.5% of the overall questions correctly (2). This is despite many universities having final year secondary school mathematics as a prerequisite at the time of the study (2). That same study found conceptual errors, which are the inability to formulate an equation from the information given, made up the majority of all calculation errors (2). This was followed by arithmetical errors, which are the inability to operate an equation, and computational errors, which are basic errors of addition, subtraction, multiplication and division (1-6). The most common errors were conceptual. This proposes that the errors are not simply random

errors that may occur when one is distracted, the conceptual errors demonstrate a fundamental lack of understanding and will occur each time a calculation is attempted. For this reason, a lack of basic mathematical comprehension must be addressed early in the tertiary education setting (7).

There is a paucity of research investigating the mathematic capability of undergraduate paramedic students in Australia, with the existing literature having come from one source (1,2,7,8). The objective of this study was to ascertain the mathematical and drug calculation ability of undergraduate paramedic students at an Australian university.

Methods

Study design

This study utilised a cross-sectional study design with a paper-based questionnaire to elicit responses about a range of mathematical calculations.

Participants

There were 185 students eligible for this study: 63 first-year students, 54 second-year students and 68 third-year students. Students enrolled in the Bachelor of Paramedicine at a Queensland university were eligible to participate in the study. There were no exclusion criteria.

Instrumentation

The paper-based questionnaire consisted of three sections including demographics, attitudes to mathematical competence, drug calculation and mathematical questions. This questionnaire has been used in a range of previous studies (1,2,6-10) and validated for face and content validity (6,8).

There were 14 questions in total. Seven questions pertained to student demographic, and seven questions that tested mathematical and drug calculation abilities. Mathematical questions contained relevant basic calculations including long division and converting fractions into decimals. The drug calculations included written scenario-like questions pertaining to drugs commonly used by paramedics (eg. dosage of midazolam for the seizing patient). Drug calculation questions included the volume of a drug being drawn up and administered, infusion rates in millilitres per hour, an infusion with drops per minute, and drug dosages in milligrams. The types of errors made by the students and the definition of the errors has been reported previously (2).

Procedure

Students were asked to participate in the study following attendance at a lecture in April 2019. They were given an information sheet, by a non-teaching staff member, which outlined the research aims, highlighted confidentiality and the voluntary nature of participation in the study. Students consented to participating in the study by completing the anonymous paper-based questionnaire and were advised they could withdraw

at any stage from the study before the Dropbox submission. Students had no knowledge of the study before receiving the information sheet and questionnaire. There were no calculators, phones or any other aids permitted when completing the questionnaire.

Data analysis

Data analysis was performed using SPSS (Statistical Package for the Social Sciences Version 26.0, IBM Corporation, Armonk, New York, USA). Descriptive statistics were used to report student demographic information and some of the drug calculation results using means, standard deviation (SD), medians, proportions, percentages and ranges. Inferential statistics, a t-test or one-way analysis of variance (ANOVA), including post hoc tests, was used to compare differences between the years of the degree, gender and student demographics for the number of correct and incorrect answers, errors, error types, entrance to the degree and high school mathematics. All confidence intervals (CI) are 95% with the results considered statistically significant if the p-value was <0.05.

Ethics

Ethics approval was obtained from Griffith Human Research Ethics Committee (reference number: 2019/010).

Results

There were 139 (75.1+%) students who participated in the study from an eligible 185, a participant rate of 75.1%. There were 62 first-year students (44.6%), 38 second-year students (27.3%) and 39 third-year students (28.1%). The proportion of students participating from each year level decreased as they progressed through the program, with 95.4% of the first-year cohort, 65.5% of the second-year cohort and 56.5% of the third-year cohort participating in the study.

There were 82 females (59%) and the majority of students were less than 25 years of age (n=120, 87%) with most in the 21–24 years of age group (n=64, 46.4%).

The majority of students did not enter the Bachelor of

Paramedicine program (n=83, 59.7%) from high school but following commencement or completion of other degree programs (n=41, 29.5%). Previous mathematics education varied from no year 12 mathematics (n=5, 3.6%) to tertiary level mathematics (n=14, 10.1%) with most completing Mathematics B (second highest level of high school mathematics) (n=55, 39.6%).

Three (2.2%) third-year students completed all the answers correctly and 75 (54.0%) students achieved 50% or less of the calculations correct. Across the year levels, 17 (12.2%) first-year students, 16 (11.5%) second-year students and 31 (22.3%) third-year students achieved more than 50% correct answers. The average score was 6.1 correct answers (SD 3.0, median 6.0, range 0–12). See Table 1 for the total correct answers and total incorrect answers.

Table 1. Total number of correct and incorrect answers by year of degree

Error type	First year (T%)	Second year (T%)	Third year (T%)	Total (T%)
Total correct	280 (16.8)	242 (14.5)	326 (19.5)	848 (50.8)
Total incorrect	464 (27.8)	214 (12.8)	142 (8.5)	820 (49.2)

Note: T% = percentage of total questions

There was a statistically significant difference between the years for total correct answers ($F=27.32$, $p<0.0001$), specifically between first and second years ($p=0.022$), first and third years ($p<0.001$), and second and third years ($p=0.002$). A statistically significant difference was noted between the years for total incorrect answers, including non-attempted questions ($F=27.32$, $p<0.0001$), specifically between first and second years ($p=0.022$), first and third years ($p<0.001$), and second and third years ($p=0.002$).

There was a total of 222 (13.3% of total questions, 27.1% of total errors) conceptual errors, 244 arithmetical errors (14.6% of total questions, 29.8% of total errors), and 30 computational errors (1.8% of total questions, 3.7% of total errors). Finally, 67 (1.8% of total questions, 3.7% of total errors) questions had no working out so error classification could not be determined (Table 2).

Table 2. Error type by year of the degree

Error type	First year (T%, E%)	Second year (T%, E%)	Third year (T%, E%)	Total (T%, E%)
Conceptual	116 (7.0, 14.1)	61 (3.7, 7.4)	45 (2.7, 5.5)	222 (13.3, 27.1)
Arithmetical	82 (4.9, 10.0)	104 (6.2, 12.7)	58 (3.5, 7.1)	244 (14.6, 29.8)
Computational	9 (0.5, 1.1)	18 (1.1, 2.2)	3 (0.2, 0.4)	30 (1.8, 3.7)
No working out	41 (2.5, 5.0)	11 (0.7, 1.3)	15 (0.9, 1.8)	67 (4.0, 8.2)
Not attempted	216 (12.9, 26.3)	20 (1.2, 2.4)	21 (1.3, 2.6)	257 (15.4, 31.3)
Total	464 (27.8, 56.6)	214 (12.8, 26.1)	142 (8.5, 17.3)	820 (49, 100)

Note: T% = percentage of total questions, E% = percentage of total errors

There was a statistically significant difference between the years for conceptual errors ($F=3.59$, $p=0.03$), specifically between first and third years ($p=0.022$). Likewise, a statistically significant difference occurred between the years for arithmetical errors ($F=17.12$, $p<0.0001$), specifically between first and third years ($p<0.001$), and second and third years ($p<0.001$). Moreover, a statistically significant difference existed between the years for computational errors ($F=11.12$, $p<0.001$), specifically between first and second years ($p<0.001$), and second and third years ($p<0.001$). A further statistically significant difference was identified between the years for conceptual errors ($F=27.77$, $p<0.001$), specifically between first and second years ($p<0.001$), and first and third years ($p<0.001$). There was no statistically significant difference between the years for no working out errors.

Females were more likely to enter the degree from high school compared to males (mean difference -0.173 , 95% CI -0.337 to -0.008 , $p=0.0$). Females were also more likely to suggest they had poor mathematical education in high school compared to males (mean difference 0.289 , 95% CI 0.056 – 0.522 , $p=0.016$). Furthermore, females were more likely to be mindful of a loss in skills level with infrequent mathematical calculations compared to males (mean difference 0.375 , 95% CI 0.089 – 0.661 , $p=0.011$). There was no statistically significant difference between females and males for the total number of correct answers or the types of calculation errors. Likewise, there was no statistically significant difference in a student's perceived mathematical and drug calculation ability and the result they obtained. Moreover, there was no statistically significant difference between a student's mathematical level at high school and their types of calculation errors.

The Cronbach's Alpha score was 0.764 demonstrating acceptable internal consistency.

Discussion

This study was the first time, to our knowledge, undergraduate paramedicine students in Queensland have had their mathematical ability assessed in the context of pre-hospital care. Although students participating in this study had been introduced to drug calculation formulae in class, the results were of concern given that just over half of the students failed to achieve more than 50% correct answers. This is consistent with similar paramedic related studies internationally, whereby students and qualified paramedics exhibited poor drug and mathematical calculations abilities (1,3,11,12). Like previous international studies, conceptual errors were the most common type of error (1-3,8,9,13-15).

Although clinical improvements and technological advancements have seen a rapid shift in paramedic practice in Australia since the early 2000s, deficiencies in the ability to perform basic drug calculations among both qualified and student paramedics and nurses has been documented (6-9). Critical interventions such

as advanced airway support, increased pharmacology and prescribing are examples of the evolving role of the paramedic (16-18). Coupled with the dynamic encounters and clinical challenges of the environment that paramedics operate within, the abilities of the attending paramedics to perform basic calculations are principle to best practice (2,7,8). This study, like similar international studies, was undertaken in a low stress classroom situation where the pressure of a sick patient requiring rapid administration of a drug or procedure was non-existent (1,3,6,9,12,19,20).

Strategies to reduce errors in drug administration have evolved within paramedic care (16-18). Bernius et al found that the use of a paediatric code card in drug calculations improved the calculation ability of paramedics from 65%, for those who did not use the card to 94% for those that did (11). There has been a shift from the hard copy printed tables and guidelines to the use of calculators, smart phone and tablet applications (16-18). While convenient, there is limited data to support these advancements in the promotion of best practice (4,17). Though the technological advancements have been perceived to reduce the risk of error, paramedics are now less inclined to maintain basic mathematical knowledge that was once paramount for the role because of the ready availability of tablet and phone applications (1,4,16-18). This study demonstrated that conceptual errors occur when the math concepts are misunderstood and formed a considerable number of the errors made. Calculators and smart phones are largely redundant when conceptual errors ensue due to the errors occurring in the maths process rather than in the numeracy of the problem.

This study replicated previous research into the abilities of the student paramedic to perform basic drug calculations in order to gain a broader picture of the current abilities of student paramedics in Australia. The number of students that entered the degree program from high school was far less than that reported in a similar previous study by Eastwood et al (8). However, most were already studying in an information technology-rich environment (inclusive of the direct high school students and current tertiary students). Just under half of the students stated they did not have issues with mathematical calculations, this was lower than that reported by Hubble et al (3) and Eastwood et al (8). Just over three-quarters of the students stated their high school mathematics education was sufficient, this was similar to the studies by Eastwood et al (8,9).

The results from this study suggest that although the entry level for the Bachelor of Paramedicine remains high, there is evidence that previously learned mathematic skills are not retained (1). There is no high school mathematics standard requirement for paramedicine programs across Australia, with Eastwood et al demonstrating that a level of high school mathematics has no influence on a student's ability to undertake unaided math and drug calculations (8). Similarly, poor results were also identified in practising paramedics who undertook a similar questionnaire in a classroom situation. Consequently, this study

suggests almost half of graduating paramedic students from this university, when placed in a situation without technological support, would fail to appropriately calculate pharmacological doses when required. Based on these findings, one can only speculate that these students would be unable to perform similar calculations when under the stress of a real-time case.

Technological advancements have supported best clinical practice. However, they are built on a fallible system, battery dependent technology; making the ultimate redundancy the paramedic on scene with a pen and paper. Digital clinical practice guidelines and smart phone applications with drug calculation calculators or charts have culturally replaced the basic mathematical ability of students and paramedics, and although the continued development of ambulance delivery is expected, the paramedic role requires redundancies such as paper-based calculations to ensure best practice can still occur in the advent of technology failure. The most common errors noted in the study were arithmetical followed by conceptual, which is supported by similar studies by Eastwood et al (2,9). Even with qualified practising paramedics, arithmetical and conceptual errors were the most common form of error (1). Moreover, these errors occurred in a classroom environment devoid of the dynamic risk and clinical distraction that is often associated with paramedical work. The fact that under these conditions the paramedic students were unable to construct or operate an equation indicates they have little chance of conducting drug calculations in a time sensitive, high pressured patient management situation.

One-fifth of students were unable to achieve more than three correct answers in total. Even more troubling was that one in 10 students did not achieve a score above one correct answer. Previous research identified approximately 63% of student paramedics failed to achieve scores of 50% or more when presented with basic mathematical calculations (2,8,9). The results of this study also reflect these findings. The number of students in this study who failed to obtain a score more than 50% correct answers was less than in other studies conducted by Eastwood et al (2,8). The study investigating qualified practising paramedics who were about to commence a higher level of paramedic education had a low total of students who failed to gain at least 50% correct answers (1).

This study suggest that students need to undertake more calculations over the duration of the three-year degree, especially calculations unaided by any form of calculator (2,8). A previous study with similar mathematical results demonstrated that a semester of study with structured tutorials involving drug calculation practise could improve the unaided mathematical ability of undergraduate paramedic students (9). There is a need for a longitudinal study to identify calculation skill improvements or degradation over the duration of a three-year degree. The study by Boyle and Eastwood demonstrated that even some qualified practising paramedics were poor at drug calculations and that there was a potential skill degradation over time in qualified paramedics (1).

Limitations

This study is potentially limited by small sample size and numbers across the years of the degree and the questionnaire being undertaken in a non-clinical classroom setting. Despite the results of this paper reflecting that of others, the participants were from one Australian university, thereby potentially limiting the external validity of the findings to students from other universities.

Conclusion

Results from this study demonstrate that paramedic students from an Australian university struggled to solve basic mathematical calculations unaided in a non-stressful classroom environment. These results are reflective of those identified at another university and may indicate a systemic problem exists that could compromise patient care in the pre-hospital setting. The findings highlight the need for universities to focus on improving strategies to ensure mastery of drug calculations to promote effective and safe practice of paramedic students on entering the workforce.

Competing interests

The authors declare no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement. Dr Boyle is the Editor-in-Chief of AJP.

Contributors

All authors have reviewed and approved the manuscript.

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