Factors Associated with the Innate Orthopaedic Ability of Veterinary Students

Original Article

FACTORS ASSOCIATED WITH THE INNATE ORTHOPAEDIC ABILITY OF VETERINARY STUDENTS

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ABSTRACT

Relatively little is known about the innate surgical ability of veterinary undergraduates. The objective of this study was to investigate if there were differences in the innate surgical ability of a cohort of 142 third-year veterinary undergraduate students to perform a series of simulated orthopaedic surgical tasks, and whether specific factors influenced their innate ability. Participants performed four simulated surgical tasks; ‘depth of plunge’ – an assessment of the ‘plunge’ depth through foam when drilling through the trans cortex of a PVC pipe; ‘3-dimensional drilling’ – an assessment of accuracy when drilling through a block of wood; ‘depth measurement’ – an assessment of the ability to correctly measure the depth of holes in PVC pipe; and ‘fracture reduction’ – where the speed and systematic reduction of a simulated fracture was assessed using a rubric score. Performance for each of these tasks was compared based on the responses to a survey. Results showed considerable variation in the innate ability of students. Previous experience performing manual tasks and using a drill was associated with an improvement in students’ ability to perform one of the four tasks (fracture reduction). Age, gender, handedness, videogame experience, building game experience, exposure to orthopaedic surgery, or desire to pursue surgery as a career were not associated with the performance of any of the tasks. A learning curve was observed for the depth of plunge task. An increased target angle led to decreased drilling accuracy for the 3D drilling task. The innate ability of veterinary students to undertake simulated surgical tasks was largely unaffected by the previous experiences we evaluated.

KEY WORDS

Innate aptitude, ability, learning curve, psychomotor skills, videogames, technical skill, tools, drilling

INTRODUCTION

Surgery is a profession which requires the acquisition of technical manual skills.[1] An individual's ability to acquire a surgical skill has been shown to be dependent on both their 'innate ability' (the base-line ability which is not a learned behaviour), as well as a 'learning curve' where repetition of a psychomotor task leads to an improvement over time.[2]

Differences in the baseline ability of undergraduate students' ability to perform both surgical and arthroscopic tasks is well recognised in the medical field.[2–4] Multiple factors which might impact on innate surgical ability have been investigated; such as age, handedness, gender, video gaming experience, intention to pursue surgical specialisation, previous experience in an operating room, sports and experience of playing a musical instrument.[4–8] The potential role of these factors, however, remains somewhat uncertain.

Previous studies have identified 'handicraft' experience and better videogame performance as factors which might improve laparoscopic skill in veterinary students.[5,9] To the authors' knowledge, no such factors' have been shown to affect Veterinary student performance for tasks associated with orthopaedic surgery. If innate surgical ability varies widely between trainee veterinary undergraduate students as is reported for medical students, identifying factors which are associated with innate ability might allow for better understanding of the nature of the variation in innate ability. Furthermore, it may be advantageous to identify individuals with superior innate ability at an early stage in their development, in order for them to consider surgical specialisation.

The primary objective of this study was to investigate if there were differences in innate surgical ability of a cohort third year veterinary undergraduate students to perform a series of simulated orthopaedic surgical tasks.[10] The secondary objective was to evaluate whether specific factors influenced innate ability. We hypothesised that there would be variation in the baseline (innate) ability of students, and that prior experience of activities that facilitate hand-eye coordination would be associated with better innate surgical skill (such as video gaming and experience with manual tasks).

MATERIALS AND METHODS

The study was carried out at the Royal (Dick) School of Veterinary Studies at the University of Edinburgh. Ethical approval was granted by the Human Ethical Review Committee (HERC) at the University of Edinburgh[a] (approval number HERC_302_18). All third-year veterinary students (2018-2019) were given the option to participate anonymously in the study. Students could undertake the simulated practical tasks without participating in the study. Firstly, students obtained a single, random, unique three-digit number printed on a piece of paper from an opaque bag. The number was used to identify them for the remainder of the practical. Students were asked to complete an electronic thirteen item questionnaire hosted on Online Surveys[b] using an iPad Mini[c] which was designed to identify experience of prior activities which might influence hand-eye coordination (see Appendix Figure 1). The questionnaire was designed to assess factors previously investigated with regard to the surgical ability of medical students; previous experience with tools, previous use of a drill and comfort using a drill, use of building games as a child (such as Lego), experience and perceived competence with video games.[5,8,11] Students were then required to complete four tasks. Tasks 1, 2 and 4 were adapted from the surgical simulation exercises outlined by Lopez et al,[10] whereas Task 3 was created by the authors. At the start of the practical session all of the tasks were demonstrated by a single supervisor (AM), and students were given unlimited time to complete the practical tasks. Students undertook the practical tasks in groups of four, with two parallel tasks being run simultaneously. Students were not time limited for any of the tasks, which typically took between two and five minutes to complete.

Task One (T1): Depth of Plunge

This exercise was designed to simulate the ‘plunge’ through soft tissues which occurs when drilling through the trans cortex of a bone, and which is minimised to reduce morbidity. A short length of PVC pipe with an external diameter of 22mm and 100mm long,[d] was attached to a piece of rigid thermoset urethane insulation material[e] with cable ties as shown in Figure 1. Each student drilled five consecutive holes through the PVC pipe using a 2.5mm diameter drill bit and Synthes Universal Drill Guide[f] and recorded their number on the insulating material. One investigator (AM) removed the pipe and measured the drill depth for each ‘plunge’ hole in mm starting at surface of the urethane using an electronic depth gauge,[g] with all materials being measured in a single session.

Task Two (T2): Three-dimensional (3D) drilling

This exercise was designed to simulate the 3D awareness required when drilling through a bone. A wooden block[h] (pine, 33mm diameter, 145mm wide, 130mm tall) was placed upright in a vice. Students were asked to drill three consecutive holes through the wood using a 2.5mm drill bit and drill guide, each time starting at a point marked with permanent marker,[i] and aiming for an exit point marked with a push pin[j] inserted on the far side of the block (thus the exit point could be both seen and palpated). Drilling was from the near side of the block, across its narrowest dimension. Three push pins were placed into the block using a plastic template to facilitate different drilling angles in relation to three marks on the on the near side of the block. The first at was zero degrees to the surface of the block horizontally and vertically (perpendicular to the block and parallel with the floor), the second was ten degrees horizontally to the left (without any vertical deviation), and the third was twenty degrees vertically downward (without any horizontal deviation). Each student wrote their identity number on the material and then drilled the three holes. A single investigator (AM) measured the deviation of the centre of the exit drill hole to the centre of the pin hole using the measurement tool in Image J [k] with all materials being measured in a single session.

Task 3 (T3): Depth measurement

A 3.5mm orthopaedic plate was fastened to four pieces of pipe of varying external diameters and materials; 10mm, 21.5mm, 25mm PVC,[d] and 15mm cross-linked polyethylene.[l] Each piece of pipe contained a central drill hole through both the simulated cis and trans cortices (Figure 3). At the beginning of the practical session the depth of each hole was measured by one of the practical demonstrators (an ECVS diplomate), using a Synthes orthopaedic depth gauge for 2.7/3.5mm cortical screws.[f] Participants' measurements were compared to the original depths and deemed correct if they were within the nearest 2mm increment of screw size. For example, if the hole measured 19mm both 19mm and 20mm were deemed correct as this would have resulted in a size 20mm screw being placed. This assessment approach simulates the clinical implications of the task a where the placement of a short screw would increase the risk of construct failure, and placement of an excessively long screw might be a source of morbidity. Each student wrote their answers on a piece of paper with their identity number. The number of correct measurements (out of four) was recorded for each student.

Task 4 (T4): Fracture reduction

A chevron fracture approximately 30mm in length was cut into a 22mm diameter cross-linked polyethylene pipe,[l] and 4mm diameter silicone rubber cord [m] was used to place the offset fragments under compression (see Figure 4). Participants were supplied with two pairs of Synthes grooved speed-lock bone reduction forceps (170mm long),[f] and one pair of Synthes self-centring bone reduction forceps (190mm long).[f] Video recordings of the participants reducing the fracture were taken using iPads mini's positioned 40cm away from the model on the opposite side of the table to ensure only the participants hands, their identify number and the model were visible, and so that their performance could be analysed at a later date. The videos were viewed by the first author (AM) on QuickTime Player[n] and this exercise was scored using a rubric (Appendix Figure 2) which accounted for the time taken to reduce the fracture, how systematic the student was, their use of the supplied instruments, and whether assistance was required. The maximum score was 8 (indicating perfect reduction) and the lowest score 0.

Statistical Analysis

Data was entered into a spreadsheet using Microsoft Excel 2016,[o] and all statistical analysis was performed with use of Minitab software.[p] All graphs were drawn using Prism 8.[q] Continuous data (Depth of Plunge and 3D drilling) were tested for normality using the Kolmogorov-Smirnov test.

The effect of the five repetitions on the depth of plunge task (T1) was assessed with One-way ANOVA. The effect of the different hole positions on 3D drilling (T2) was compared using the Kruskal-Wallis test and pairwise comparisons were then made using the Mann-Whitney test. The averaged measures of continuous data (the mean of the last four depth of plunge measures – T1, and the mean 3D drilling deviation – T2) were used in subsequent analyses, and log transformed to ensure normality.

One-way ANOVA adjusted for multiple comparisons using the Benjamini-Hochberg Procedure was used to assess the effect of continuous measures (depth of plunge and 3D drilling) on how the individual factors investigated in the questionnaire affected the students' performance in these tasks in a univariate manner. For ordinal measures (depth measurement and fracture reduction); ordinal logistic regression adjusted for multiple comparisons using the Benjamini-Hochberg Procedure was used to assess if any of the factors investigated in the questionnaire affected the students' performance in these tasks in a univariate manner. Correlation between different question responses was measured using the Spearman Rank test.

RESULTS

Questionnaire results

Of the 174 students that were invited to take part in the study; 142 consented of which 129 successfully completed the questionnaire.

Demographics of participants

The participants were 14% male (n = 18), 85% female (n = 110), and 1% non-binary (n = 1). Ninety-four percent of respondents classified themselves as right-handed (n = 121), 5% as left-handed (n = 6), and 1% as ambidextrous (n = 2). Participants were predominantly aged in their early twenties, with 45% aged 21 years old (y) or under (n = 58), 45% aged 22y – 25y (n = 58), 8% aged 26y – 30y (n = 11), 1% aged 31y – 35y (n = 1), and 1% aged 36y – 40y (n = 1).

Prior experience

The majority of respondents had used a drill at least once before (74%, n = 95). Twenty two percent of respondents indicated that they did not feel at all comfortable using a drill (n = 29), 54% (n = 69) were ‘a little’ to ‘somewhat’ comfortable, with 24% (n = 31) being either ‘fairly’ or ‘very’ comfortable. At least some exposure to manual work was reported by 93% of respondents (n = 119), which was defined as ‘manual work involving the use of hand or power tools; drilling holes, placing screws, bolts, nails or other fixings into wood, metal or plastic’. Ten percent of students were more experienced having done this on at least twenty occasions (n = 13). Ninety two percent of students (n = 119) reported at least some previous exposure to building games (such as Lego or Meccano). Most students had been engaged in video gaming at some point in the past (84%, n = 108), with 33% reporting more than ten years of video game playing (n = 42). Most students had either never previously viewed an orthopaedic procedure (39%, n = 51), or only viewed one once or twice (42%, n = 54). Nine percent of students had viewed three or four procedures (n = 12), and 10% had viewed more than five procedures (n = 12). Most students were undecided about wanting to perform orthopaedic surgery in their careers (67%, n = 87), with 7% not wanting to do any (n = 9). Twenty two percent did want to do orthopaedic surgery (n = 28), and 4% wanted to become orthopaedic specialists (n = 5). A full summary of questionnaire results can be seen in Appendix Table 1.

Results for Tasks 1 – 4

T1 - Depth of plunge

A block containing five holes was present for 117 respondents, with 124 drilling at least three holes. The mean first depth for all students was 10.63mm (5 – 27.9), and the mean of the last four holes was 9.24mm (4.03 – 17.15). The $\log_{10}$ mean depth of plunge of the first hole drilled was significantly greater when compared to all other holes, ($p = 0.004$). For this reason, it was decided to use the mean of the last four attempts as a measure of innate skill, on the basis that the true innate ability could only be assessed once the students understood the task completely. The performance of the students for each of the five holes is outlined in Figure 5. None of the questionnaire factors investigated affected the mean depth of plunge of these four attempts.

3D Drilling

For this task, data for all three holes was present for 126 respondents, with 125 drilling a minimum of two holes. The performance of the students for each of the three holes is outlined in Figure 6. The range of deviation for all targets was 0.2mm – 13.7mm. The median deviation for holes one, two and three was 2.55mm, 2.50 and 3.7mm respectively with the third hole (twenty degrees downward) being 1.2mm less accurate than first or second ($p < 0.001$). None of the factors investigated affected the accuracy of an individuals' drilling, as assessed by the 'average deviation'.

Depth Measurement

For this exercise, recorded measurements were analysed for 124 of the 129 questionnaire respondents. The range of measurements was 21mm under to 10mm over the accurate length. An appropriate measurement for optimal screw size selection in all holes was correctly identified by 44% of the participants ($n = 55$), with 27% measuring three holes correctly ($n = 33$), 19% measuring two holes correctly (n = 24), 6% measuring one hole correctly ($n = 7$), and 4% not measuring any of the holes accurately ($n = 5$) – see Appendix

Figure 1. None of the factors investigated were associated with an improvement or deterioration in the number of accurately measured pipes.

Fracture Reduction

For the fracture reduction task, a score was assigned to 121 of the 129 respondents. In 8 respondents the recording was incomplete so could not be analysed. Fracture reduction was performed well by 51% of students (n = 62), who scored 7 or 8 points out of a possible 8. This task was performed moderately well by 28% of students who scored 5 or 6 points (n = 34), and poorly by 21% of students who scored fewer than 5 points (n = 25) – see Appendix Figure 2.

As students' level of experience with a drill increased (Question 2), so too did their fracture reduction score (Table 1 and Appendix Figure 3). The greatest difference was noted between respondents who had never used a drill (mean score of 5.3), and those who had used one on more than ten occasions (mean score of 7.1, OR 6.94; 95% CI: 2.35 – 20.48; $p <$ 0.001). As students' level of confidence with a drill increased (Question 3), so too did their fracture reduction score (Table 1 and Appendix Figure 4). Differences were observed for pairwise comparisons between respondents who were 'not at all confident' using a drill (mean score of 4.9), and those who were either 'somewhat' or 'fairly' confident (who achieved a mean score of 6.6 and 6.7 respectively, p = 0.001). Only three students indicated that they were 'very' confident using a drill, meaning that a statistically significant comparison of their performance was not possible. There was a positive correlation between questions two and three (r = 0.47, 95% CI 0.315 – 0.601).

As students' level of experience performing manual tasks increased, so too did their fracture reduction score (Table 1 and Appendix Figure 5). Students who had never done any manual work attained a mean score of 4.8, whereas those who reported having done so on more than twenty occasions achieved a mean score of 7.0 (OR 12.6; 95% CI: 2.6 – 60.0; p = 0.001).

DISCUSSION

The results of this study support the first hypothesis that variation exists in the baseline ability of undergraduate medical and veterinary students to perform surgical simulation tasks. Prior experience of activities that facilitate hand-eye coordination was only associated with better innate surgical skill with one of the four tasks assessed, and thus the second hypothesis could only be partially accepted. These findings are consistent with previous studies.[2,4–6.] The baseline ability of veterinary students to perform traditional open surgery tasks (drilling) has previously been described[9.]

Both previous experience and confidence with a drill (Q2 and Q3) and performing manual tasks (Q4) were associated with an improvement in the ability of third-year veterinary students to successfully reduce a simulated fracture (T4). Manual tasks (as we defined them) involve both manual dexterity and problem-solving capability, which could be expected to intuitively explain why undergraduate veterinary students with greater experience of them were more likely to reduce a simulated fracture well. A recent systematic review did not find any effect of experience operating (non-surgical) tools on technical performance.[12] The effect of drilling experience and confidence specifically on fracture reduction was unexpected. The most likely explanation is that good performance of this task represents a proxy for experience performing manual tasks generally, although other reasons (such as type II error) cannot be excluded. It was also interesting that drilling experience and confidence was not associated with students' ability on the other drilling tasks (T1 and T2). The present study did not identify any differences in ability based on students' age, gender, handedness, videogame experience, exposure to surgery, or desire to pursue surgery as a career, which is consistent with the findings of previous studies of students undertaking simulated tasks.[12] There was also no association with previous building game play. It should be noted that the role of video gaming in innate surgical skill is currently disputed. There are multiple studies which support an effect of previous gaming experience on innate surgical ability[8,9,13–16] as well as many that do not.[3,5–7] A recent systematic review of this topic concluded that playing video games and/or musical instruments did not significantly promote skills for microsurgery.[1]

This study demonstrated the presence of a learning curve for the depth of plunge task (T1), with the first attempt having a greater error than the subsequent four attempts. The improvement noted after the first attempt was likely the result of individuals becoming familiar with the equipment and the task, and the sensation of the drill plunging as it exited the far-side of the pipe. This supports the findings of previous studies which document the presence of a learning curve for surgical simulation exercises in medical students and surgical residents.[17–22]

The results of task two (T2), revealed that a twenty-degree angulation ventrally from horizontal resulted in considerably less accurate drilling than when no angulation or only minor horizontal deviation was necessary. This supports the findings of a previous study which reported increased angulation of a drill bit with respect to a surface, results in decreased accuracy in both veterinary undergraduate students, veterinarians and veterinary specialist surgeons.[23]

The results of task three (T3) were surprising. We expected this to be a straightforward task, however only 44% of students (55 / 124) measured all four holes correctly. The ability to measure screw depth is important. The placement of a short screw that fails to engage the trans cortex has obvious implications for overall construct stability.[24] Although very rare, the risk of damage to neurovascular structures from over-long orthopaedic screw placement has also been documented in the human literature, potentially leading to neuropathy, blood vessel damage and even limb ischaemia.[25,26]

There were several limitations of the present study. Firstly, performance of the four tasks was limited to a simulated environment, which may not directly translate to comparable performance in open surgery. In addition, a relatively small number of tasks were able to be assessed given the significant time constraints and large number of students taking part. These tasks only represent a small subset of the necessary practical skills that an orthopaedic surgeon must master in order to achieve competence. Assessing different and/or a wider range of skills may lead to different results. When considering the effect of the questionnaire factors on the students' performance, it should be noted that not all categories were represented evenly. There were a small number of male students, left-handed students and students older than 25 years of age that were in the cohort which means the results in relation to these factors should be interpreted with caution. Furthermore, although relatively few students elected not to take part (32/174), the ability to 'opt out' means that the potential for 'self-selection bias' is not excluded.

In conclusion, the results of this study show that there is considerable variation in the innate baseline ability of third-year Veterinary students to perform simulated tasks associated with orthopaedic surgery. Previous experience performing manual tasks and using a drill was associated with superior ability in only one of the four tasks (T4 fracture reduction). This study did not, therefore, identify any clear background factors associated with superior innate orthopaedic surgical ability.

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CONFLICT OF INTEREST

The authors report no conflict of interest

FIGURE CAPTIONS

Figure 1: Apparatus used for T1, the depth of plunge task. Participants drilled holes on five pre-marked dots from left to right.

Figure 2 (A & B): A, reverse side of the apparatus for T2, the three-dimensional drilling task. There were three separate targets per student present vertically which corresponded to the same colour pin, and 4 students were able to use each wooden block. B, Front side of the apparatus for the '3D drilling' task where three dots drawn vertically 1cm apart (not visible).

Figure 3: Apparatus created for T3, the depth measurement task, with a depth gauge inserted in the second hole to be measured. The pipe insulation was affixed adjacent to the nearside of the plate with cable ties to obstruct direct visualisation of the pipe

Figure 4: Apparatus constructed for T4, the fracture reduction task, with large gelpi retractors and bone holding forceps in situ.

Figure 5: Dot-plot of the five attempts for every student for T1, the 'depth of plunge' task, with a line at the median value.

Figure 6: Dot-plot demonstrating the median deviation from the target for the three holes drilled for all students in T2, the '3D drilling' task. The median value has been marked with a line.

Table 1: Results of ordinal logistic regression for the effect of questionnaire answers on fracture score (T4), including adjusted P Values (Benjamini-Hochberg procedure). Significant pairwise fracture score comparisons have been included.

[a] HERC_302_2018

[b] onlinesurveys.ac.uk

[c] Apple, Cupertino, California, U.S.A. 95014

[d] FloPlast Ltd, Kent, UK, ME103FP

[e] Kingspan Insulated Panels, Flintshire, UK, CH87GJ

[f] DePuy Synthes Vet, West Chester, PA, U.S.A 19380

[g] Preciva, Guangdong, China, 518000

[h] MKM Building Supplies, Edinburgh, UK, EH142TF

[i] Sharpie, Newell Brands, Atlanta, Georgia 30328, USA

[j] Dius LLC, LA, California 70508 USA

[k] ImageJ V.1.51; National Institutes of Health, Bethesda, Maryland

[l] John Guest Ltd, West Drayton, Middlesex, UK, UB78JL

[m] Polymax Ltd, Hampshire, UK, GU350FJ

[n] QuickTime Player Version 10.5, Apple Inc

[o] Excel 2016, Microsoft, Redmond, Washington

[p] Minitab software, Version 19, Pennsylvania, USA 16801

[q] Prism 8, GraphPad Software, San Diego, CA 92108