Influence of an Exercise Program, Muscle Strength, Proprioception, and Arm Length on Veterinary Students' Bovine Pregnancy Diagnosis Accuracy

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ABSTRACT

Bovine pregnancy diagnosis (PD) by transrectal palpation (TRP) is an important skill for veterinary graduates. Factors influencing students' PD accuracy were investigated to optimize bovine PD by TRP training without increasing live animal exposure. The objective was to determine whether arm length and strength, proprioception, and exposure to a 6-week exercise training program were significantly associated with students' PD accuracy. Veterinary students (n = 128) who had previously received formal theoretical and practical training in bovine TRP and PD (live cows and TRP simulators) were assessed for PD accuracy on live cows. Prior to assessment, arm muscle strength measurement, an exercise program, and additional TRP sessions on Breed'n Betsy® simulators and live cows were offered to the students. Seventy-eight students volunteered to participate in the arm length measurement, muscle strength, and proprioception testing. Of these, 35 randomly allocated students completed a 6-week exercise program, after which muscle strength was reassessed. Each student performed PDs on six cows of which the pregnancy status, ranging from 6 weeks to 9 months pregnant or not pregnant, was predetermined by an experienced veterinarian. PD accuracy was measured as sensitivity and specificity, being defined as the proportion of pregnant or nonpregnant cows, respectively, correctly identified by the student. It is concluded that hand grip strength and participation in an exercise program are significant predictors of veterinary students' PD accuracy. Implementation of an exercise program aimed at improving grip strength in the veterinary curriculum is a novel approach to improve bovine TRP and PD training.

Key words: veterinary education, bovine pregnancy diagnosis, transrectal palpation training, veterinary students, isokinetic muscle strength testing

INTRODUCTION

Bovine pregnancy diagnosis (PD) by transrectal palpation (TRP) is one of the most frequently performed procedures in bovine practice[1] and is therefore an important skill for veterinary graduates.[2] While it is widely used in veterinary practice and is of economic importance,[3–6] it has recently been shown that fourth-year students' (of a 6-year course) overall PD accuracy (pregnancy status and stage) was lower than what is considered acceptable accuracy.[7–11] It was furthermore reported that student specificity (ability to correctly identify nonpregnant cows) was lower than sensitivity (ability to correctly identify pregnant cows), and additional student training on nonpregnant cows was recommended.[10] However, providing additional TRP exposure in existing training programs is challenging since live cow training opportunities within veterinary courses are already limited and do not offer the extensive exposure needed to ensure competency.[10,12–15] Furthermore, TRP training opportunities outside the veterinary course are not easily accessible for veterinary students.[10,14] To overcome the shortage of live cow palpation exposure, several investigations into TRP and PD training using simulators and best training options for live cow palpations have been performed.[10,12–14,16–20] The effectiveness of simulators including the Breed'n Betsy®[a] and the Haptic Cow[b] has been explored. [10,12,16–20] While simulator training is superior to theoretical instruction,[16,20] live cow training results in better student PD accuracy and is therefore advised to be done in addition to simulator training to optimize learning outcomes.[10,12] Having students identify specific reproductive landmarks such as uterine horns and ovaries with quantitative measurements and choosing cows that are easy to handle had a positive impact on TRP training through better student engagement.[13] The importance of quantitative measurements is supported by a recent study,[21] which shows that students' ability to estimate ovary size, identify uterine position, and palpate the presence or absence of intrauterine fluid was positively correlated to PD accuracy. Previously reported factors associated with higher overall sensitivity of bovine PD by TRP were a farming background and a career interest in mixed animal practice.[10]

Palpation of the female reproductive tract is performed through the rectal wall after insertion of a lubricated gloved hand into the cow rectum. The arm and hand movements and technique for palpation of cervix, retraction of the uterus, following uterine horns, and palpation of the ovaries[22] require an unusual physical effort with repetitive motions that can cause fatigue, especially in examiners not used to TRPs. Therefore, it is hypothesized that arm strength may influence PD accuracy and that an exercise program aimed at improving arm muscle strength could improve PD accuracy among students. Other factors that might influence palpation accuracy are proprioception and arm length.

Proprioception was first described by Sherrington in 1906 as "the perception of joint movement and positioning in space in the absence of visual feedback."[23(p.221)] Proprioception is critical for controlling motor activities, and the importance of proprioceptive feedback during sensorimotor performance has been described.[24] Individuals who lack proprioceptive sense while the motor systems remain fully intact show deficits in motor control.[25] These deficits include, but are not limited to, poor endpoint accuracy, reduced control of multi-segmental dynamic movements, and an inability to perform complex movement sequences.[25] Transrectal palpations involve body positioning and movement independent of vision. It is therefore hypothesized that poor proprioception could lead to lower palpation accuracy and decreased PD accuracy, while good proprioception might be linked to higher PD accuracy.

In order to optimize and investigate alternative approaches to bovine PD training that do not include live cow palpations, factors influencing student performance need to be explored. The first objective of this study was to determine whether arm length and strength and proprioception influence the accuracy of bovine PD by TRP in fifth-year veterinary students. The second objective was to determine whether a 6-week exercise program can improve arm strength and students' PD accuracy. It was hypothesized that greater arm length and strength and good proprioception are positively correlated with PD accuracy. It was furthermore hypothesized that a 6-week exercise program would improve arm strength and students' PD accuracy. Although it is possible that suboptimal proprioception could be addressed with physiotherapy, such a procedure was not addressed in this study.

MATERIALS AND METHODS

Participants and Setting

Study participants were fifth-year veterinary students (*n* = 128) who had successfully passed the veterinary reproduction module during their fourth year of study. The University of Pretoria's 6-year Bachelor of Veterinary Science (BVSc) program includes nine semesters of didactic pre-clinical training and three semesters of clinical work-integrated learning.[26] After obtaining written, informed consent, a subset of 78 students voluntarily enrolled into the arm length, arm strength, and proprioception testing component of the experiment, of which 40 students were initially randomized within five predetermined stratified strength categories (8 per category) to participate in the 6-week exercise program. Strength categories were based on best repetition shoulder extension (in Newton meters [NM]) as determined through isokinetic muscle strength testing (shoulder extension/flexion, speed: 60° per second for five repetitions) expressed as a percentage of body weight (BW) (in kg): category 1: > 80% BW; category 2: 71%–80% BW; category 3: 61%–70% BW; category 4: 51%–60% BW; category 5: < 50% BW. Of the 40 students allocated to the exercise program, 35 participated and completed the program. Students (*n* = 128) were allocated to one of three groups. Group 1 (G1) consisted of students who volunteered for the strength testing and participated in the exercise program (*n* = 35); group 2 (G2) consisted of students who volunteered for the strength testing but did not participate in the exercise program (*n* = 43; this group includes the five students who were initially allocated to the exercise group but did not participate); and group 3 (G3) consisted of students who did not participate in strength testing or the exercise program (*n* = 50). All three student groups (*n* = 128) underwent additional fifth-year TRP and PD training, as well as PD assessment (Figure 1).

Student TRP and PD Training Prior to the Experiment

The fourth-year veterinary curriculum of the University of Pretoria's 6-year program includes a 1-year module on reproduction of all domestic species.[26] Bovine, small stock, small animal, and equine reproduction are taught separately throughout the year, and one examination assesses knowledge and skills for all species. The bovine part of the veterinary reproduction module covers aspects of male and female reproduction, including TRP and PD. The fourth-year TRP and PD practical training consisted of three sessions per student presented in separate sessions to groups of 19 to 23 students at a time. The training periods were standardized for all student groups. The first TRP training session included three components: inspection of abattoir-obtained female reproductive organs, palpation of the nonpregnant Breed'n Betsy® (BB) models, and palpation of nonpregnant live cows with lecturer guidance. Abattoir-obtained reproductive organs included nonpregnant uteri and pregnant uteri of various stages in efforts to demonstrate important signs of pregnancy and pregnancy staging (including various fetal sizes, cotyledons, asymmetrical uterine horns, and corpora lutea of pregnancy). The variety of abattoir reproductive organs was relatively similar for all student groups. The first TRP training session was presented either before or just after the theoretical lectures on PD. The second and third practical TRP training sessions followed 2 to 3 months after the PD theory component. The second TRP training session consisted of bovine PD via TRP on BB models. The BB models allowed for the palpation of weekly pregnancy stages from 6 to 20 weeks of gestation.[10] The third TRP training session consisted of bovine PD via TRP on live cows, 1 week after the PD training on BB models.

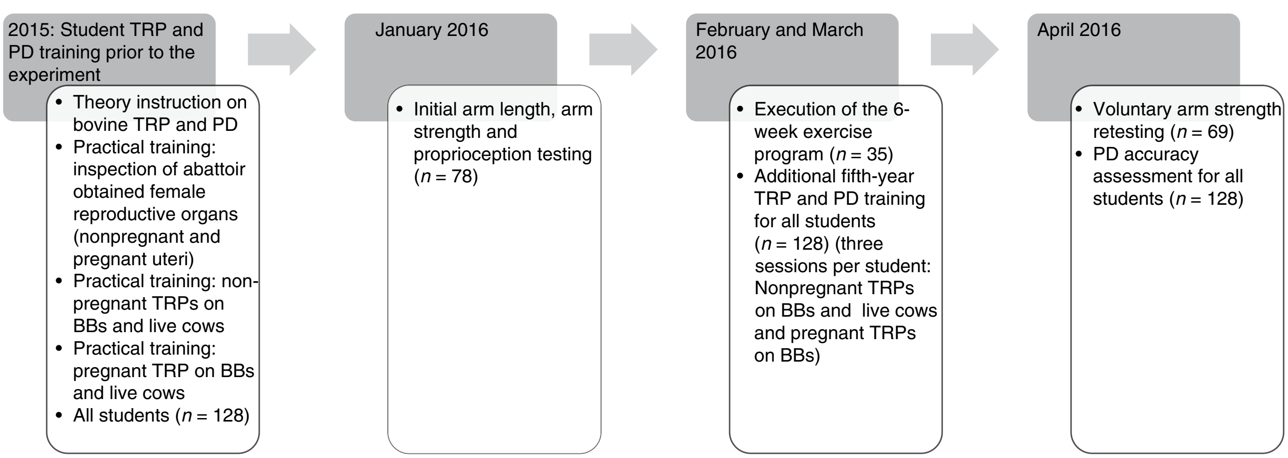


Figure 1: Schematic time line display of the TRP and PD training, strength measurements, exercise program, and PD assessment for 128 veterinary students

TRP = transrectal palpation; PD = pregnancy diagnosis; BB = Breed'n Betsy®

Training focused on determining pregnancy status (pregnant or not pregnant) and estimating stage of pregnancy.

Additional Fifth-Year TRP and PD Training for the 128 Study Participants

All 128 fifth-year veterinary students received additional supervised bovine TRP training in February and March 2016 (Figure 1). The additional bovine TRP training included three separate training sessions presented to groups of 19 to 23 students at a time. The first training session consisted of palpation of nonpregnant BB models. Training session two involved nonpregnant live cow palpations. Training session three entailed bovine PD via TRP on BB models. The BB models allowed for palpation of weekly pregnancy stages from 6 to 20 weeks of gestation. Students were also encouraged to arrange additional TRP exposure outside the formal veterinary course.

Arm Strength Testing, Arm Length Measurement, and Proprioception Testing

Testing was performed at the High Performance Centre, LC De Villiers Campus of the University of Pretoria, Hatfield, Pretoria, South Africa. All grip and isokinetic muscle strength testing was executed by experienced biokineticists. Arm length measurement and proprioception testing was done by a physiotherapist (CAE). On arrival at the High Performance Centre, students' identification, date of birth, dominant hand, and BW were recorded. Each student was weighed using a mechanical scale.

Arm Muscle Strength Testing

Arm muscle strength measurement was subdivided into grip strength, to determine hand, wrist, and forearm muscle strength, and shoulder extension and flexion, to measure upper arm, shoulder, and back muscle strength. Muscles collectively tested via grip strength were forearm flexors (flexor digitorum superficialis, digitorum profundus, and pollicis longus muscle), forearm extensors (extensor carpi radialis longus, carpi brevis, and carpi ulnaris), and finger and thumb muscles (flexor pollicis longus, digitorum superficialis and digitorum profundus, extensor pollicis longus and brevis, extensor digiti minimi, extensor indicis, and extensor digitorum). Muscles collectively evaluated via shoulder extension were the deltoid, infraspinatus, latissimus dorsi, teres major, and triceps brachii muscle. Muscles collectively evaluated via shoulder flexion were the pectoralis major, anterior deltoid, biceps brachii, coracobrachialis, teres major, and subscapularis muscle.

Grip Strength Measurement

Grip strength was measured in kilograms using the hand-held digital Grip Strength Dynamometer T.K.K 5401.[c] Students were standing upright with their feet hip-width apart and toes pointing forward while the arm was flexed at a 90-degree angle to the shoulder joint, palm facing down (Figure 2F). The dynamometer was grasped between the fingers and the palm at the base of the thumb. Students were then asked to squeeze the hand grip with maximal effort for 5 seconds. Right- and left-hand grip strength was measured individually.

Isokinetic Shoulder Extension and Flexion Strength Measurement

The Humac®/Norm™ testing system[d] was used for the isokinetic muscle strength testing. Student details (name, date of birth, gender, dominant hand, body weight) were entered into the computer system before onset of data collection to uniquely identify each data sheet and to enable the system to normalize absolute strength to BW. Absolute muscle strength was measured in torque (NM).

The isokinetic testing evaluated muscle strength of the whole arm through shoulder extension or flexion to achieve a pre-selected fixed speed (degrees per second) against an accommodating resistance (Figure 2A–D). The standard settings for speed (degrees per second) and repetitions as per manufacturer's instructions were used to measure both maximum strength (peak torque at slow speed and high resistance) and work ability (torque measurements at high speed for more repetitions and less resistance) of shoulder extension and flexion. Since torque is produced in an effort to overcome the pre-selected speed, the resistance created by the Humac®/Norm™ testing system varies to exactly match the force applied at every point in the range of motion.

Measurements were performed with students in supine position (Figure 2A–D) while holding the handle of the lever tightly. Both arms were tested individually. During the performance of the flexion and extension movements, students were asked to keep the wrist locked in neutral position. Each student was first tested at settings for maximum strength (speed: 60° per second) and asked to do five repetitions. After a 1-minute break, work ability testing was done at settings with less resistance (speed: 180° per second) but more repetitions ($n = 10$). Strength data for shoulder extension and flexion were recorded simultaneously.

Arm Length Measurements

Left and right arm length was measured using a measuring tape from the shoulder joint (acromion) to the radial styloid process at the wrist and captured in centimeters. Acromion and radial styloid process were palpated, and length measurements were done on fully extended arms.

Proprioception Testing

Contralateral joint position (CJP) matching task was used to assess proprioceptive acuity by matching a reference joint angle with the opposite (i.e., contralateral) arm.[25] Since all PD assessment palpations were done left-handed by all students, the left arm proprioceptive acuity was of interest and evaluated. Students were seated upright on a chair and blindfolded (Figure 2E). The physiotherapist (CAE) then placed the student's right arm (shoulder, elbow, and wrist) in a random position (Figure 2E). The student was requested to position the contralateral left arm in exactly the same matching position as the right arm.[25] The CJP matching was performed five times at random positions, and a point was allocated for each accurately matched position adopted by the student. The students' proprioceptive acuity scores were determined by the number of positions that they could accurately match. The accuracy of matching was visually observed by two trained independent observers and noted as a score out of 5 (1 point per position). An exact match of all random positions was recorded as a 5/5 proprioception score. A 3/5 proprioception score would indicate that the student matched three of the five random positions.

The 6-Week Exercise Program

The exercise equipment for the program was purchased from Hitech Therapy CC.[e] It consisted of yoga mats, Powercore exercise balls (65 cm, 150 kg carrying capacity), and different strengths of TheraBand® latex exercise bands. TheraBand® exercise bands were bought in five color-coded levels of resistance. Resistance is described in kilograms at 100% elongation. TheraBand® information and allocation to students based on arm strength per percentage BW is shown in Table 1. After an initial 2 weeks of training, a subjective assessment based on individual student perception of exertion during the exercises was used to progress the student to a higher level of resistance band, where applicable. Progression of resistance bands was repeated after week 4 for the last 2 weeks of the exercise program, where applicable.

The 45-minute exercise program was presented three times a week (Mondays, Wednesdays, and Fridays) from 1:00 p.m. to 1:45 p.m. in

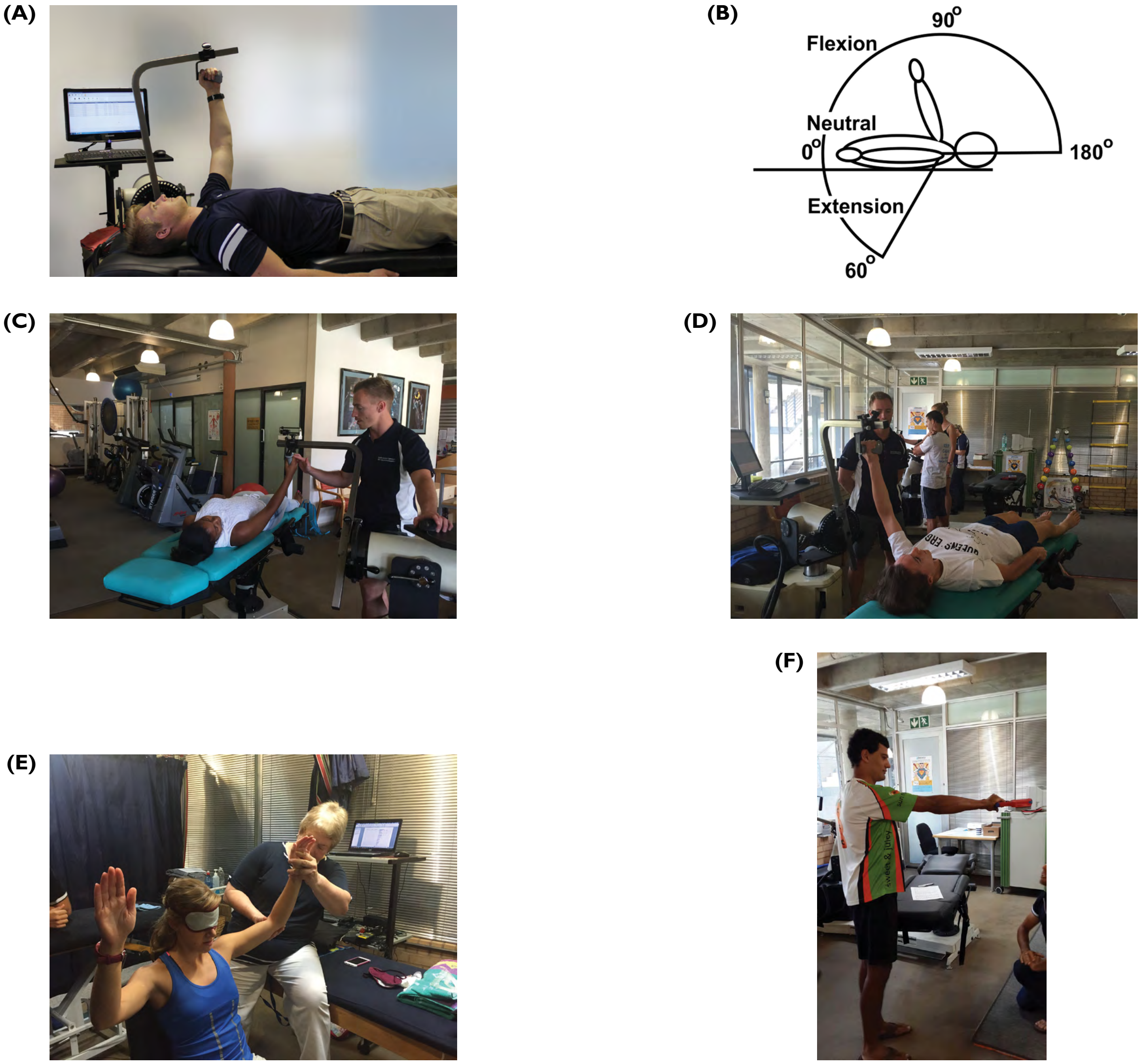


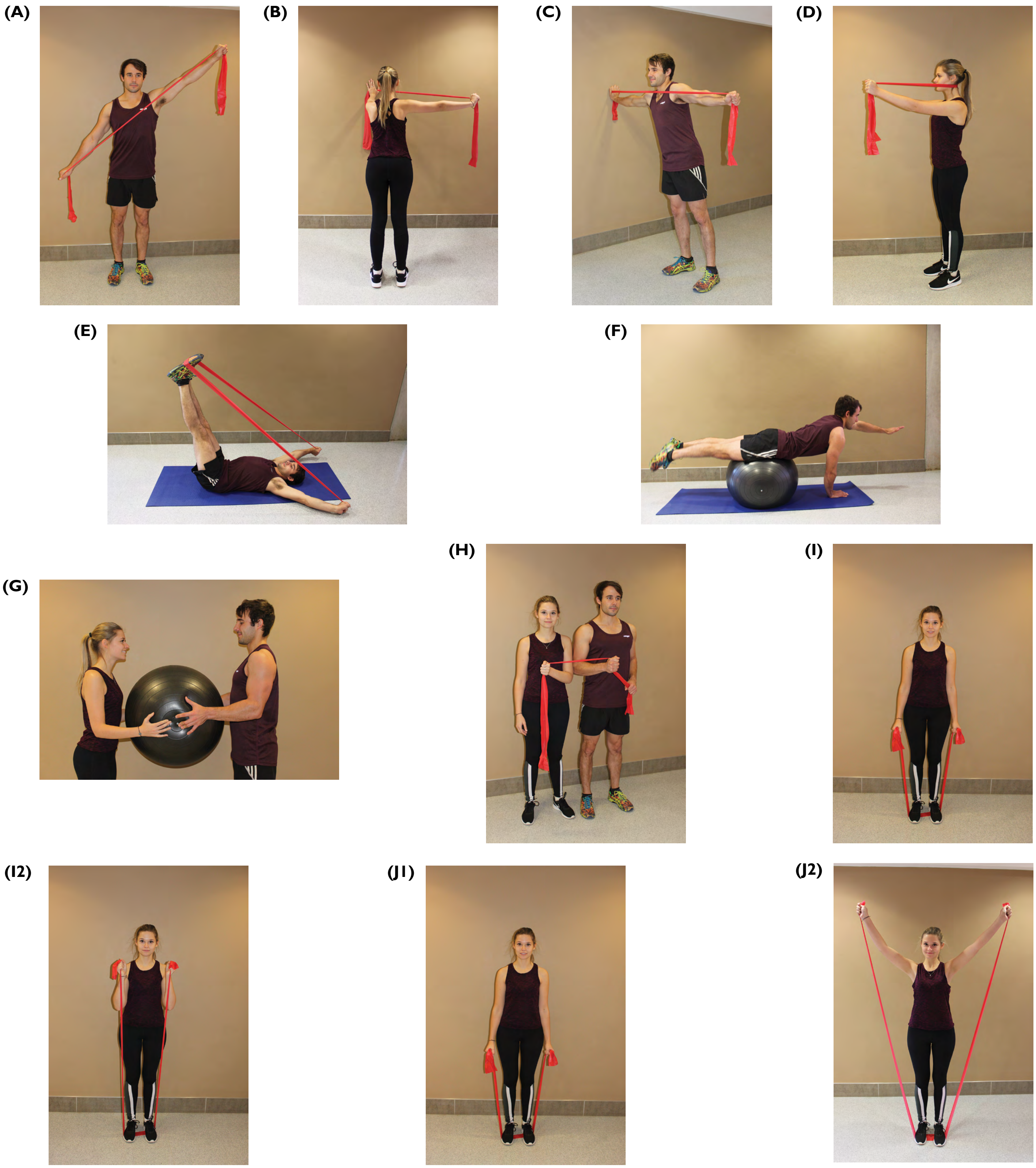
Figure 2: (A), (B), (C), and (D): Shoulder extension and flexion test using the Humac®/Norm™ testing system. (E): Proprioception test using contralateral joint position (CJP) matching task. (F): Grip strength test using the using the hand-held digital Grip Strength Dynamometer T.K.K 5401

Table 1: TheraBand® information and allocation to students based on arm strength (Newton meter per kilogram body weight [NM/kgBW])

TheraBand® color	TheraBand® thickness	Resistance in kg at 100% elongation	TheraBand® users	Allocation of TheraBands® based on shoulder extension in Nm/kgBW at the beginning of the exercise program
Yellow	Thin	1.3	Beginner	< 40
Red	Medium	1.7	Beginner and intermediate	40–60
Green	Heavy	2.1	Intermediate	60–70
Blue	Extra heavy	2.6	Intermediate and advanced	> 70
Black	Special heavy	3.3	Advanced	Not allocated at the beginning of the program

the skills laboratory of the Faculty of Veterinary Science, University of Pretoria. The exercise instructor demonstrating and supervising each exercise session was a physiotherapist who designed the exercise program and allocated the TheraBands® based on student strength prior to the start of the 6-week exercise program (Table 1). Exercises were performed to the rhythm of music. The program was divided into individual student exercises as well as paired exercises. Each student performed all exercises during the sessions. The sessions consisted of a warm-up, progressive strengthening and endurance, and a cool-down period. The warm-up period of 5 to 10 minutes was used for elevation, retraction, protraction, and depression of scapulae; rolling the scapulae through full range motion; shoulder flexion (elevation) and extension; shoulder abduction and adduction; elbow flexion and extension; and hand warm-up exercises (quick reciprocal flexion adduction and extension abduction of the fingers, commonly known as *finger flicking*).

The progressive strengthening and endurance part consisted of exercises done sitting, kneeling, and lying prone over an exercise ball, and standing and lying on the mat (Figure 3). General exercise principles were applied to prevent students from performing abnormal movements to compensate for poor central (trunk) and/or proximal joint control. Students were therefore asked to perform all arm exercises in standing position with their knees slightly flexed while stabilizing the core (trunk muscles). TheraBands® were held using whole hand grip and not wrapped around hands or wrists at any stage (Figure 3A–D, H–J). Exercises focused on grip strength, lower arm, upper arm, shoulder girdle, and trunk muscles. An illustration of exercise types is shown in Figure 3.



(K1) **(K2)** **(L1)**

(L1) **(M1)** **(M2)**

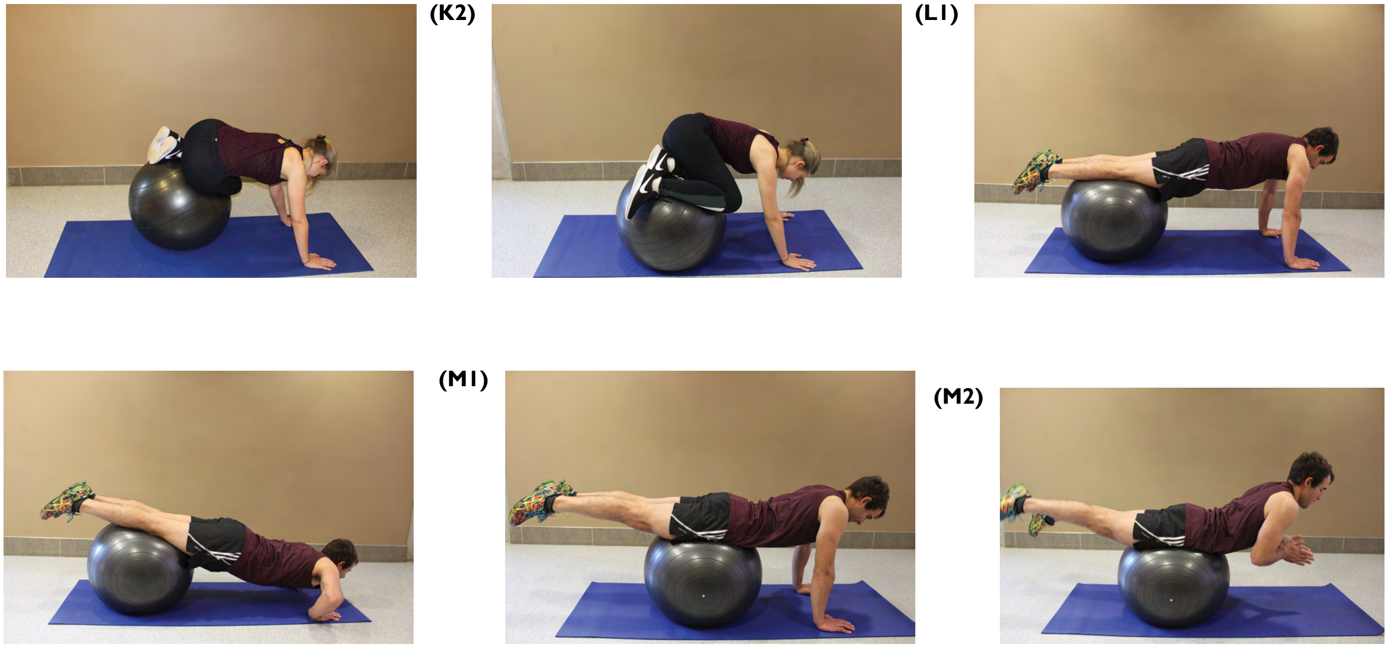


Figure 3: Exercises

(A). **Standing, stabilize core:** diagonal stretching the TheraBand; reverse the action in the opposite diagonal. **Avoid** low back extension and shoulder girdle elevation. **Muscles working:** trunk stabilizers, shoulder flexors, abductors, back extensors, elbow extensors, and hand muscles. Alternative arm: shoulder extensors, abductors, elbow extensors, and hand.

For external rotation, maintain position, but grasp the TheraBand with the opposite hand and perform external rotation.

(B). **Standing, stabilize core and one (right) arm stabilize in 90° flexion against the wall:** Rotate trunk away from the wall by horizontally abducting and extending the opposite arm. **Avoid** low back extension and shoulder girdle elevation, lifting of the medial border of the scapula of the supporting arm. **Muscles working:** trunk stabilizers; shoulder (glenohumeral) abductors, and shoulder girdle (scapulae) adductors (asymmetrical arm exercise). Alternate stabilizing arm. **Progression**: stand with feet further away from the wall.

(C). **Standing, stabilize core and one (right) arm stabilize in 90° abduction against the wall:** horizontal abduction of the opposite arm. **Avoid** elevation of the shoulder girdles. **Muscles working:** trunk stabilizers, shoulder (glenohumeral) abductors, and horizontal (shoulder girdle) adductors. Alternate stabilizing arm. **Progression**: Stand with feet further away from the wall.

Muscles work in different ranges and types of muscle work.

(D): **Standing and stabilize core:** Wrap TheraBand around the base of the skull, shoulders both in 90° horizontal flexion and elbows in 90° flexion. Extend elbows while holding neck stabile in a lengthening position. **Avoid** active neck extension, shoulder girdle elevation. **Muscles working:** trunk and leg muscles to stabilize during exercise. Shoulder flexors, elbow extensors, and hands.

(E): **Supine lying with hip flexion and knee extension. Middle of TheraBand wrapped around the feet and holding the two ends of the TheraBand in the hands (shoulders in 90° flexion):** Do flexion abduction with the arms while keeping the elbows in extension. **Avoid** hyperextension of the low back (keep low back on the floor). **Muscles working:** Trunk and hip flexors stabilizing, shoulder flexors, abductors, trunk extensors.

(F): **Prone lying on an exercise ball under the hips with arms stabilizing on the floor, stabilize with arms on the floor.** Stretch one arm forward while stabilizing with the other arm. Alternate the arms stretching forward. **Avoid** hyperextension of the back, trunk rotation when lifting one arm, and lifting of the medial border of the scapulae. **Muscles working:** trunk, hip, and one arm stabilizers. Arm stretching forward—glenohumeral flexors and abductors, shoulder girdle adduction, anterior and posterior trunk rotators stabilizing.

(G): **Stand opposite a partner. Stabilizing the trunk. Both partners hold the ball between them with the elbows in 90° flexion.** Both partners attempt to pull or rotate the ball from the other partner's hands. Both partners attempt to keep the ball still. **Avoid** trunk movement. **Muscles working:** trunk, arm, and leg muscles stabilizing. Focus is on strengthening the forearm, wrist and hand muscles.

(H): **Stand next to a partner and stabilize core**: Both partners grasp the TheraBand with their hands, with the elbows in flexion and hands facing forward. Both partners rotate their hands toward the abdomen while keeping the elbow against the body. **Avoid** movement of the body instead of medial rotation of the arm. **Muscles working:** Shoulder (glenohumeral) adduction and medial rotation.

(I): **Stand on the middle of the TheraBand holding the two ends in the hands with elbows in extension**: Stabilize core while flexing the elbows through full range of motion. **Avoid** shoulder girdle elevation and extension of the back. **Muscles working:** Trunk and leg muscles to stabilize, elbow flexors, and hands.

(J): **Stand on the middle of the TheraBand, elbows in extension and holding the two loose ends of the TheraBand in the hands:** Do flexion abduction of the arms with elbows in extension to full glenohumeral range of motion. **Avoid** extension of the lower back. **Muscles working**: trunk and legs stabilizing shoulder (glenohumeral) flexors, abductors, and shoulder girdle extension and adduction.

(K): **Kneel on an exercise ball and stabilize with hands on the floor.** Rotate hips and knees to alternative sides while maintaining stabilizing position of the hands on the floor. **Avoid** flexion and extension of the neck (keep head in mid-position). **Muscles working:** trunk rotators and stabilizers, hip stabilizers, arm stabilizers, glenohumeral rotator cuff.

(L): **Prone lying on an exercise ball under the thighs/knees/lower legs with arms stabilizing on the floor:** Push upper body up with the arms—ensure that medial border of the scapulae is flat against the thorax. **Avoid** hyperextension of the trunk and winging of the scapulae. **Muscles working:** trunk and arms stabilizing, shoulder flexors, elbow extensors, wrist flexors.

(M): **Prone lying on an exercise ball under the hips with arms stabilizing on the floor:** While maintaining balance, clap the hands. **Avoid** hyperextension of the neck. **Muscles working:** trunk stabilizers followed by back extensors, hip extensors, knee extensors, and plantar flexors.

The cool-down period of 5 minutes was used for stretching and resistance-free (free-active) exercises of all upper limb and trunk muscles that were strengthened. Stretching of the following muscles was done: triceps surae, biceps brachii, rhomboids, pectoralis minor and major, and trunk extensors, as well as wrist and fingers.

Arm Muscle Strength Retesting

Students in the arm length, arm strength, and proprioception testing part of the experiment (G1 and G2) voluntarily took part in the retesting session in April 2016 (Figure 1). All previously described measurements were repeated for each student. Students who had participated in the exercise program were also asked to complete a questionnaire (Questionnaire A) about the exercise program (Appendix 1).

PD Accuracy Assessment

Students' bovine PD accuracy via TRP was assessed as described previously.[10,21] All students (n = 128) visited a commercial Nguni beef cattle herd 3 weeks after the third additional TRP training session. Each student completed a questionnaire (Questionnaire B) on student background, previous bovine TRP and PD experience, and career interest.[10] Following completion of the questionnaire, each student was allowed a total of 12 minutes to palpate six cows transrectally. The pregnancy status and stage of these cows were predetermined by a specialist veterinarian with more than 10 years of experience. A student's stage of pregnancy estimation was considered to be correct if it was within 1 month of the finding of the specialist for cows less than 6 months pregnant according to the specialist, and if it was within 2 months of the finding of the specialist for cows equal or greater than 6 months pregnant according to the specialist. All student palpations were performed left-handed due to the examination crush setup on the farm. Each student's pregnancy diagnoses (pregnancy status and stage) were recorded on an individual data capture sheet against the appropriate cow number, and students were blinded to each other's diagnoses.[10,21] Cows were not formally randomized but taken into the crush in a convenient manner out of a group of available cows. Each cow was only used and palpated on one of the three assessment days.

Statistical Analysis

Statistical Analysis of Strength Measurements for First Test and Retesting

Differences in strength measurements were calculated by subtracting the baseline measurements from the values determined at the end of the study. The normality assumption of these differences was assessed by calculating descriptive statistics, plotting histograms, and performing the Anderson-Darling test.[f] Muscle strength differences, which appeared normally distributed, were compared between the students who participated in the exercise program with those who did not using independent t-tests. Statistical analysis was performed using available software (IBM SPSS Statistics Version 24[g]), and results were interpreted at $p < .05$.

Statistical Analysis of Factors Affecting PD Accuracy

Sensitivity (Se) was defined as the proportion of cows determined to be pregnant by the specialist veterinarian that were correctly identified by the student. *Stage-corrected sensitivity* was defined as the proportion of pregnant cows in which pregnancy stage was correctly identified by the student. Specificity (Sp) was defined as the proportion of nonpregnant cows as determined by the specialist veterinarian correctly identified by the student. Overall accuracy was calculated as the proportion of cows in which the student determination of pregnancy was the same as the specialist veterinarian's.

Students were divided into three groups for the calculations: G1 consisted of students who volunteered for the strength testing and participated in the exercise program (n = 35); G2 consisted of students who volunteered for the strength testing but did not participate in the exercise program (n = 43); and G3 consisted of students who did not participate in strength testing or the exercise program (n = 50).

Correlations between student-level pregnancy diagnostic accuracy (Se, Sp, accuracy) and muscle strength measures were estimated using Spearman's rho. The primary exposure of interest was student participation in the exercise program.

Sensitivity is the probability that the student correctly recognized a pregnancy, and therefore, factors associated with the sensitivity of student pregnancy diagnoses were evaluated only within cows that were determined as pregnant by the specialist veterinarian.

A generalized linear model approach was used with the outcome being the dichotomous diagnosis (pregnant/nonpregnant) of the student. Random effect terms were included in these models for student and cow to account for the study design, in which a single student examined multiple cows and each cow was examined by multiple students.

The effects of student factors on the PD were evaluated by screening each possible predictor one by one in univariate analyses that included these variables as fixed effects in the model. All variables in which $p < .20$ in these screening models were subsequently evaluated using a multivariable approach that included all variables identified in the screening models. Multivariable models were fit using a manual backward stepwise procedure. Variables were removed from the multivariable model when the student t statistic for the variable's coefficient was $p > .05$. The variable with the largest p value was removed first, and the model was run again.

The removal of variables continued until all remaining factors were $p < .05$. Confounding was assessed by calculating the percent change in the odds ratio for the treatment group variable (primary exposure of interest) between the model with the factor and the model after factor removal. If removal of a variable caused a > 20% change in the odds ratio, then the variable was classified as an important confounder and added back into the multivariable model. Models evaluating the factors associated with student specificity were fit using the same procedures as described for sensitivity but within the subset of cows identified as nonpregnant by the specialist veterinarian. Commercial software was used for all statistical analyses (IBM SPSS Statistics Version 24), and significance was set as $p < .05$.

Ethical Considerations

This study was approved by the Animal Ethics and Research Committee of the University of Pretoria (Protocol V122–15). No cow was palpated more than three times in one session during the experiment.

RESULTS

Study Participants

The study population consisted of 128 fifth-year veterinary students, of which 96 were female and 32 were male (75% and 25%, respectively).

All 128 students had passed the veterinary reproduction module during their fourth year of study in 2015. During the fourth-year training, students performed an average of five nonpregnant TRPs (live cows and BBs) and an average of 16 pregnant TRPs (live cows and BBs) during the training module.

Analysis of correctly completed questionnaires B (n = 126) showed that 39%, 33%, 17%, and 9% of students indicated a career interest in small animal practice, mixed animal practice, other (specialized production animal practice, wildlife, state veterinary services, research, industry), and equine practice, respectively. Only a very small proportion (2.4%) of students did not have a stated career interest. Students' palpation exposure and experience during fourth and fifth year is summarized in Table 2.

Of the 78 students who volunteered for the initial testing (arm length measurements, grip and arm strength testing, proprioception testing) in January 2016, 69 (88%) were female and 9 (12%) were male.

Of the 78 students who volunteered for the initial testing, 69 (88%) participated in the second testing in April 2016. Out of the 40 students allocated to the 6-week exercise program, 35 participated in and completed the program. Two students allocated to the exercise group (G1) did not attend any sessions, and three students were excluded from the exercise group after the first 2 weeks because of inconsistent and irregular attendance. The five students who did not participate in and did not complete the exercise program were removed from G1 and analyzed with G2 participants. All 35 students who completed the exercise program participated in the second testing session in April 2016.

Allocation of students into the predetermined strength categories is shown in Table 3.

Table 2: Fourth- and fifth-year student transrectal palpation (TRP) exposure

Fourth-year TRP exposure				Students *N* (%)
Only exposed to TRPs within the veterinary course				84 (67)*
Some additional exposure with a veterinarian				16 (13)†
Some additional exposure without a veterinarian				26 (21)‡
Number of bovine TRPs performed by the end of fourth year				**Students *N* (%)**
< 10				84 (67)
10–25				27 (21)
25–50				13 (10)
> 50 (range: 50–300)				3 (2)
Fifth-year TRP exposure	**Students *N* (%)**			
	G1	**G2**	**G3**	**Total§**
Only exposed to TRPs within the veterinary course	26 (74)	33 (77)	37 (82)	96 (78)
Some additional exposure with a veterinarian	3 (9)	4 (9)	4 (9)	10 (8)
Some additional exposure without a veterinarian	6 (17)	6 (14)	5 (11)	16 (13)
Number of bovine TRPs performed by the end of fifth-year TRP training				**Students *N* (%)**
< 10				93 (74)
10–25				30 (24)
25–50				2 (1.6)
> 50 (range: 50–300)				1 (< 1)

G1 = group 1; G2 = group 2; G3 = group 3
*22 were in G1, 31 were in G2, and 31 were in G3.
†4 were in G1, 3 were in G2, and 9 were in G3.
‡9 were in G1, 9 were in G2, and 8 were in G3.
§Five students had missing data.

Out of 78 students who volunteered for the initial testing, 75 (96%) were right-handed.

Arm Length and Proprioception Results

Arm length (n = 79) ranged from 49.5 cm to 64.0 cm (mean ± *SD*: 54.7 ± 3.2 cm). Proprioception scores (n = 70) were recorded as 2/5 for 2 students, 3/5 for 19 students, 4/5 for 33 students, and 5/5 for 25 students (median: 4/5).

Grip Strength Results for the Initial Testing

Right-hand grip strength (kg) ranged from 17.1 kg to 52.4 kg (mean: 29.2 ± 7.4 kg), with a significant gender difference (mean: 26.9 kg and 43.0 kg for female and male students, respectively; $p < .001$).

Left-hand grip strength did not differ from right-hand grip strength ($p = .206$), ranged from 16.6 kg to 50.7 kg (mean: 28.6 ± 8.1 kg), and also differed by gender (mean: 26.0 kg and 44.0 kg for female and male students, respectively, $p < .001$).

Exercise TheraBand® Allocation

The initial TheraBand® allocation for the 40 exercise group students were beginner (n = 10, yellow), beginner to intermediate (n = 7, red), intermediate (n = 17, green), and advanced (n = 6, blue).

After 2 weeks of training with the initially allocated TheraBands® (Table 1), all participating students progressed to the next level of resistance bands. After week 4, students progressed again to the next level of resistance bands for the last 2 weeks of the exercise program.

Effect of the Exercise Program on Arm and Grip Strength

While participation in the 6-week exercise program did not increase shoulder extension and flexion strength, it did increase right-hand grip strength ($p = .025$). The change of grip strength values for G1 (students who volunteered for the strength testing and participated in the exercise program) and G2 (students who volunteered for the strength testing but did not participate in the exercise program) reported as means (95% CI) were 2.31 (0.46, 4.16) and −.38 (−1.86, 1.10) for right grip strength ($p = .025$), and 1.00 (−0.38, 2.38) and .24 (−1.03, 1.50) for left grip strength ($p = 0.413$), respectively.

PD Assessment, Accuracy, Sensitivity, and Specificity Results

On the day of the PD assessment, 374 of 771 (49%) student palpations were performed on pregnant cows, of which 262 (70%) were on cows < 6 months pregnant, and 112 (30%) were on cows ≥ 6 months pregnant. A total of 125 students each palpated six cows in the 12-minute time limit. One student did not finish on time and only palpated five cows. Two students only examined nonpregnant cows initially and were subsequently assigned two

Table 3: Allocation of students into predetermined stratified strength categories based on initial arm strength (NM/kgBW) for the best repetition shoulder extension (speed: 60° per second for five repetitions).

Strength categories	Students (*N*)
1 (> 80%)	13
2 (71%–80%)	17
3 (61%–70%)	18
4 (51%–60%)	18
5 (< 50%)	13

NM/kgBW = Newton meter per kilogram body weight
Note: speed = 60° per second for five repetitions

pregnant cow palpations. This occurred because the order that cows entered the crush was haphazard, without consideration of pregnancy status. Compared to the diagnoses provided by the experienced veterinarian, the mean overall student accuracy of PD was 61% (95% CI: 55%–65%) for pregnancy status alone and 31% (95% CI: 27%–36%) for pregnancy status with correct stage. The mean sensitivity (correctly identify pregnant cows) was 79% (95% CI: 73%–83%). The mean specificity (correctly identify nonpregnant cows) was 42% (95% CI: 35%–49%).

Sensitivity and specificity estimates for the different experimental groups (G1, G2, and G3) are presented in Table 4.

Correlation between PD Accuracy, Arm Length, Proprioception, and Strength Measurements

Left shoulder extension and flexion strength, arm length, and proprioception based on the initial strength testing results ($n = 78$) did not correlate with the students' overall palpation accuracy, sensitivity, or specificity (Table 5). However, higher left grip strength was associated with higher student specificity ($p = .039$, Table 5).

Associations between Student-Level Variables and PD Sensitivity

Within the univariate analysis that investigated each variable independently, student sensitivity was higher when palpating cows > 6 months pregnant, but no other variables were significant (Table 6). Students were 3.2 times more likely to correctly identify pregnant cows when 6 or more months pregnant compared with cows that were only 2–3 months pregnant (reference category).

The multivariable analysis investigates the combined effects of multiple variables, and these results (Table 7) show that students who participated in the exercise program (G1) had higher PD sensitivity compared with nonparticipating students (G3). Students who participated in the exercise program were 2.5 times more likely to correctly identify a pregnant cow compared with students who did not participate in the biometric screening or exercise programs (reference category). Furthermore, male students and students who did not indicate mixed practice as a career interest had higher PD sensitivity.

Table 4: Estimates for overall sensitivity, stage-corrected sensitivity, and specificity (95% CI) for different experimental groups of students

PD accuracy measure	Testing and exercise (G1, n = 35)	Testing and no exercise (G2, n = 43)	No testing and no exercise (G3, n = 50)
Overall sensitivity	88% (80%–94%)	70% (60%–79%)	79% (71%–85%)
Stage-corrected sensitivity	30% (20%–41%)	18% (12%–28%)	20% (14%–27%)
Specificity	48% (35%–61%)	39% (27%–53%)	39% (29%–50%)

PD = pregnancy diagnosis; G1 = group 1; G2 = group 2; G3 = group 3

Table 5: Spearman's rho correlation (p) between measures of rectal palpation accuracy and left* biometric arm strength measures obtained from 78 fifth-year veterinary students in South Africa

	Accuracy measure NM (p)			
Biometric measure	Accuracy	Sensitivity	Sensitivity stage	Specificity
Ext_5rep-L in Torque (NM)	0.057 (0.639)	0.026 (0.830)	−0.022 (0.856)	0.063 (0.607)
Ext_5rep-L%BW	−0.044 (0.717)	−0.015 (0.904)	0.003 (0.983)	0.055 (0.655)
Ext_10repL	0.111 (0.365)	0.079 (0.519)	−0.024 (0.848)	0.066 (0.595)
Ext_10rep-L%BW	0.036 (0.767)	0.063 (0.607)	0.061 (0.619)	0.067 (0.589)
Flex_5rep-L	0.092 (0.454)	0.060 (0.623)	0.001 (0.991)	0.055 (0.656)
Flex_5rep-L%BW	−0.015 (0.902)	0.033 (0.791)	0.038 (0.754)	0.075 (0.545)
Flex_10rep-L	0.097 (0.426)	0.011 (0.930)	0.037 (0.761)	0.066 (0.593)
Flex_10rep-L%BW	0.015 (0.900)	0.022 (0.860)	0.167 (0.169)	0.135 (0.272)
GS-L	0.171 (0.161)	0.112 (0.360)	0.163 (0.181)	**0.252 (0.039)**
Arm length (cm)	0.071 (0.543)	−0.005 (0.964)	0.162 (0.166)	0.010 (0.934)
Proprioception	0.017 (0.886)	−0.090 (0.436)	−0.002 (0.985)	0.041 (0.727)

NM = Newton meter; Accuracy = total proportion correctly identified per student; Sensitivity = proportion of pregnant cows correctly identified by each student; Sensitivity stage = proportion of pregnant cows in which pregnancy stage was correctly identified by the student; Specificity = proportion of nonpregnant cows correctly identified by each student; Ext_5rep_L in Torque (NM) = first test shoulder extension five repetitions peak torque (Newton meters) left arm; Ext_5rep_L%BW = first test shoulder extension five repetitions peak torque left arm in % body weight; Ext_10rep_L in Torque (NM) = first test shoulder extension 10 repetitions peak torque (Newton meters) left arm; Ext_10rep_L%BW = first test shoulder extension 10 repetitions peak torque left arm in % body weight; Flex_5rep_L in Torque (NM) = first test shoulder flexion five repetitions peak torque (Newton meters) left arm; Flex_5rep_L%BW = first test shoulder flexion five repetitions peak torque left arm in % body weight; Flex_10rep_L in Torque (NM) = first test shoulder flexion 10 repetitions peak torque (Newton meters) left arm; Flex_10rep_L%BW = first test shoulder flexion 10 repetitions peak torque left arm in % body weight; GS-L = grip strength left

Note: Significant positive correlations are presented in bold.

*Only left arm strength measures were included, as all palpations were done left-handed by all students.

Table 6: Univariate associations between student-level variables and pregnancy diagnosis sensitivity for 128 fourth-year veterinary students in South Africa

Variable	Level	Parameter estimate ($\hat{\beta}$)	Odds ratio (95% CI)	*p*
Exercise program	Yes*	0.718	2.05 (.97–4.35)	.062
	No†	−0.455	0.64 (.35–1.14)	.129
	Non-participant‡	Referent	–	–
Gender	Female	−0.590	0.56 (.28–1.09)	.086
	Male	Referent	–	–
Background	Farm	−0.529	0.59 (.29–1.20)	.146
	Mixed	0.084	1.09 (.53–2.22)	.817
	City	Referent	–	–
Previous experience	None	Referent	–	–
	Non-veterinarian	−0.407	0.67 (.34–1.31)	.235
	With veterinarian	0.123	1.13 (.44–2.92)	.799
Additional experience	Yes	0.168	1.18 (.59–2.40)	.641
	No	Referent	–	–
Career choice	Mixed practice§	−0.553	0.58 (.28–1.17)	.126
	Other	−0.116	0.89 (.44–1.80)	.891
	Small animal	Referent	–	–
Grip strength—left	< 25	Referent	–	–
	25–30	−0.366	0.69 (.28–1.74)	.433
	> 30	−0.021	0.98 (.35–2.72)	.968
Pregnancy stage	2–3 months	Referent	–	–
	4 months	−0.054	0.95 (.35–2.55)	.914
	5 months	0.698	2.01 (.86–4.72)	.109
	6 months	1.179	3.25 (1.36–7.76)	**.008**
	7–9 months	1.174	3.24 (1.36–7.71)	**.008**

*G1 = Students who participated in testing and the exercise program (*n* = 35)
†G2 = Students who participated in testing but not the exercise program (*n* = 43)
‡G3 = Students who did not participate in testing or the exercise program (*n* = 50)
§Includes specialized production animal and state veterinary medicine
Note: Significant positive correlations are presented in bold.

Table 7: Multivariable associations between student-level variables and pregnancy diagnosis sensitivity for 128 fourth-year veterinary students in South Africa

Variable	Level	Parameter estimate ($\hat{\beta}$)	Odds ratio (95% CI)	*p*
Exercise program	Yes*	.908	2.48 (1.13–5.44)	**.024**
	No†	−.155	.87 (.45–1.64)	.637
	Non-participant‡	Referent	–	–
Gender	Female	−.856	.43 (.20–.92)	**.030**
	Male	Referent	–	–
Career choice	Mixed practice§	−.643	.53 (.29–.95)	**.033**
	Other career	Referent	–	–

*G1 = Students who participated in testing and the exercise program (*n* = 35)
†G2 = Students who participated in testing but not the exercise program (*n* = 43)
‡G3 = Students who did not participate in testing or the exercise program (*n* = 50)
§Includes specialized production animal and state veterinary medicine
Note: Significant positive correlations are presented in bold.

Table 8: Univariate associations* between student-level variables and pregnancy diagnosis specificity for 128 fourth-year veterinary students in South Africa

Variable	Level	Parameter estimate ($\hat{\beta}$)	Odds ratio (95% CI)	*p*
Exercise program	Yes†	.345	1.41 (.72–2.77)	.315
	No‡	.013	1.01 (.72–2.77)	.972
	Non-participant§	Referent	–	–
Gender	Female	−.688	0.50 (.26–.96)	**.037**
	Male	Referent	–	–
Background	Farm	.201	1.22 (.55–2.71)	.621
	Mixed	−.156	.86 (.40–1.82)	.683
	City	Referent	–	–
Previous experience	None	Referent	–	–
	Non-veterinarian	.953	2.60 (1.27–5.29)	**.009**
	With veterinarian	.470	1.60 (.68–3.75)	.278
Additional experience	Yes	.838	2.31 (1.15–4.63)	**.018**
	No	Referent	–	–
Career choice	Mixed practice¶	.581	1.79 (.82–3.89)	.143
	Other	.724	2.06 (.99–4.31)	.054
	Small animal	Referent	–	–
Grip strength—left	< 25	Referent	–	–
	25–30	.542	1.72 (.62–4.73)	.293
	> 30	1.392	4.02 (1.40–11.5)	**.010**

*No multivariable model significantly fit these data.
†G1 = Students who participated in testing and the exercise program (*n* = 35)
‡G2 = Students who participated in testing but not the exercise program (*n* = 43)
§G3 = Students who did not participate in testing or the exercise program (*n* = 50)
¶Includes specialized production animal and state veterinary medicine
Note: Significant positive correlations are presented in bold.

Associations between Student-Level Variables and PD Specificity

Within the univariate analysis, students with a grip strength of > 30 kg had higher PD specificity. Students with a left-handed grip strength of > 30 kg were four times more likely to correctly identify nonpregnant cows compared with students who had a grip strength of < 25 kg (reference category). Furthermore, male gender, previous TRP experience with a non-veterinarian, and additional experience were associated with higher PD specificity (Table 8). Male students were twice as likely as female students to correctly identify nonpregnant cows. Student participation in the exercise program did not have an effect on PD specificity.

Student Feedback on the 6-Week Exercise Program

The response rate to Questionnaire A was 77%. Analysis of correctly completed Questionnaires A (*n* = 27) showed that 93% (*n* = 25) enjoyed participating in the exercise program; 82% (*n* = 22) thought that their muscle strength had improved through participation in the exercise program. A total of 14 students (52%) said they could feel a difference while performing rectal examinations after the exercise program, while 13 students (48%) said they could not. All 14 students who said they could feel a difference while performing rectal examinations stated that they could do more TRPs more comfortably without becoming tired.

Additional benefits other than increased arm strength and endurance mentioned by students were experiencing fun while exercising, socializing, comradery, that exercising was relaxing and a stress release in between classes/studying, free and regular physical exercise, and learning new exercises. What students did not enjoy was that the exercise program was offered during lunchtime and on Friday afternoons. More time flexibility, a better venue, and inclusion of more students were mentioned as suggestions for improvement to such a program. Seventy percent of students (*n* = 19) thought an exercise DVD or a mobile application (app) would be useful and utilized by students. Seven students (26%) did not think that either an exercise DVD or an app would be useful or utilized by students, and one student was not sure. One reason given for why a DVD or app would not be useful or utilized by students was that students would not be inclined to do additional activities in their free time.

DISCUSSION

The attempt to improve student bovine TRP training follows a worldwide trend to optimize TRP training and to investigate alternatives to live cow palpation training.[10,12,14,16–18,20,27]

The main findings of this study are that student participation in the 6-week exercise program was correlated to a higher PD sensitivity compared with students who did not participate, and that a left-handed grip strength of > 30 kg was linked to higher PD specificity. This is interesting, since participation in the exercise program increased right grip strength but not whole arm strength.

A possible explanation for this could be that the exercise program increased bilateral arm muscle endurance rather than total muscle strength. While *strength* is defined as the ability of specific muscle groups producing maximum force to overcome a resistance within a single exertion, *endurance* is defined as the ability of a muscle group that can generate submaximal force over a sustained amount of time or through repeated movements.[28] In other words, "Strength endurance is the specific form of strength displayed in activities that require a relatively long duration of muscle tension with minimal decrease in efficiency."[29]

Since the isokinetic strength measurements using the Humac®/Norm™ testing system are used to measure total muscle strength in torque (NM) and not endurance, an increase in endurance among the participants might not have been noticed. This could also explain why none of the shoulder extension and flexion strength measurements were correlated to PD accuracy. The fact that only right-hand grip strength improved through participation in the exercise program might be explained by the fact that 34 out of 35 exercise group students (97%) were right-handed. This is in conformance with estimates that 90% of the general human population are right-handed,[25] and that the dominant hand in right-handed people is consistently stronger than the nondominant left hand.[30] Executing exercises using the dominant hand is generally easier and might have resulted in more improvement compared with the nondominant left hand. We hypothesize that in right-handed participants, the exercise program would not have restored the strength balance between left and right hand and forearm.

Grip strength includes hand (finger and thumb muscles), wrist, and forearm (forearm flexors and extensors) muscle strength and is an important indicator for upper limb strength and endurance.[31,32] The fact that a left-handed grip strength of > 30 kg was correlated to higher PD specificity suggests that strength of forearm flexors and extensors as well as hand muscles are more important for TRPs than total strength of upper arm, shoulder, and trunk muscles (deltoid, infraspinatus, latissimus dorsi, teres major and triceps brachii, pectoralis major, biceps brachii). It could further indicate that the generally higher upper limb strength and endurance linked to higher grip strength[31,32] has a positive effect on PD accuracy. The application of this would be to modify the exercise program to concentrate on upper arm, shoulder, and trunk muscle endurance training and include more specific exercises targeting grip strength.

Grip strength testing is executed using hand-held, readily available dynamometers that could be used by veterinary training institutions for grip strength testing. This might motivate students to exercise to improve grip strength and to track progress during an exercise program. The finding that left-handed grip strength of > 30 kg is only linked to increased PD specificity but not sensitivity suggests that palpating nonpregnant uteri requires not only more practice but also more strength and might play an important role in the general lack in specificity compared with sensitivity of PD of veterinary students.[10,21]

Students' overall PD accuracy (pregnancy status alone) and PD accuracy including pregnancy stage was lower than what is considered acceptable accuracy for veterinarians,[9,7,8,11] and is in agreement with previous findings.[10,21] Overall PD accuracy for experienced large animal practitioners has been reported as high as 99.7% for TRPs performed from day 35 of pregnancy, with a sensitivity of 100% and a specificity of 99.4%.[8] While students at this stage in their studies are not expected to perform at these accuracy levels, the reported 31% overall accuracy (including pregnancy stage) is very low compared with the reported values of large animal practitioners. The additional palpation sessions (TRPs on nonpregnant and pregnant BBs and nonpregnant live cows) offered to the students as refresher training during their fifth year was not sufficient to ensure acceptable palpation skills. This is in accordance with previous studies[10,12] and highlights that additional TRP exposure is essential.

Student specificity was similarly low, as described in a previous report.[10] This confirms the importance of using nonpregnant cow TRPs to obtain PD skills and that TRP training should focus on nonpregnant cow palpations to improve PD skills and student PD specificity as previously described.[10] This approach is further supported by the findings of this study that students' previous and additional palpation experience was associated with higher PD specificity (Table 8). The lower sensitivity of pregnancy detection for cows in early stages of pregnancy is in agreement with previous findings.[9,10]

Arm length and proprioception were not significantly associated with students' overall palpation accuracy, sensitivity, or specificity. Therefore, shorter students or veterinarians with relatively shorter arms are not necessarily at a disadvantage when performing bovine TRPs. The reason that proprioception did not have an effect on PD accuracy could be explained by the fact that the median proprioception score was 4 out of 5, which indicates that most students had a good perception of joint movement and positioning in space in the absence of visual feedback.[25] If more students had low initial proprioception scores, an association with palpation ability might have been apparent; therefore, further research into this using a more diverse population in terms of proprioceptive ability is warranted.

Other student-level variables that were associated with PD accuracy were gender, career choice, and previous and additional experience. PD sensitivity and specificity were higher for male students. Grip strength being higher in men than in women has been well described,[33–36] and this is shown in our data as well. However, our data do not confirm or rule out the hypothesis that gender difference in grip strength is an important explanation of gender differences in PD accuracy reported here and elsewhere. Further studies are warranted to investigate these gender differences in order to target PD by TRP training of veterinary students, especially since female students are overrepresented in veterinary student populations.

A career choice other than mixed practice was associated with higher PD sensitivity. This is interesting, as a previous study found that students from a farming background with an interest in mixed practice had higher PD sensitivity.[10] The authors of that study hypothesized that previous animal exposure and experience gained from growing up on a farm and interest in large animals seems to be positively correlated with large animal clinical skills, including bovine PD via TRP.[10] The fact that this study shows the opposite might indicate that career interests and large animal skills might be influenced by additional factors in different student cohorts. They might also be influenced by the fact that the previous study investigated a fourth-year student cohort, and this study used a fifth-year student cohort (out of a 6-year course). Background and initial experience might be overcome by additional exposures related to advancement within the veterinary course.

Interestingly, previous and additional TRP experience was only significantly associated with student PD specificity, not sensitivity. This suggests the importance of additional TRP exposure to improve PD skills by improving PD specificity, since specificity is a particular weakness among veterinary students.[10] Only 34% of students had previous TRP exposure outside of formal veterinary training, which is similar to that reported in a previous report.[10] The fact that the majority of students did not have any additional TRP exposure outside of what they were exposed to during the fourth-year training confirms that despite being very important, bovine PD opportunities outside veterinary training programs are limited and not easily accessible to students.[10,14]

Limitations of the current study include the evaluation of only a single cohort of students, self-selection into the initial muscle testing program, and the multiple independent statistical tests performed on collected data. The first two aspects could lead to selection bias, and generalizability of the findings cannot be guaranteed for this reason. The alpha error rate of 5% (statistical significance level) implies that 5% of all statistical tests performed would be expected to be significant even when no true association exists within the data. It is not possible to differentiate false-positive findings from valid mathematical associations. The positive results presented in the manuscript should therefore be interpreted in combination with these potential limitations.

It was encouraging that almost all students enjoyed participating in the exercise program, that 52% of students reported that they could feel an improvement while performing rectal examinations, and that they could do more TRPs more comfortably without becoming tired. The fact that many students mentioned additional benefits such as experiencing fun, relaxation, and stress relief through participation in the exercise program is interesting, since stress-related disorders are common among veterinary students worldwide.[37–45] The Centers for Disease Control declares exercise to be one of the most important activities to improve physiological as well as psychological health.[46,47] Psychological benefits of exercising include a reduced risk for depression and anxiety, improved mood, better sleep quality, and better cognitive functioning.[37,46,47] However, veterinary students generally have a heavy workload in- and outside the classroom, combined with stress of academic performance, which can cause other life goals such as physical activity to become less of a priority.[37] It has been previously identified that students have different motivators to exercise.[37,48] Therefore, if participation in an exercise program not only benefits arm strength and indirectly palpation accuracy but also general student well-being, then these benefits might be sufficient motivators to include exercise programs into veterinary curricula in the future. It is currently planned to modify the exercise program at the University of Pretoria and make it available through an online platform (via a mobile app) to all students interested in participating. Students will then be able to exercise on their own time and choose a venue of their convenience as indicated in the student feedback.

CONCLUSION

Hand grip strength and participation in an exercise program are significant predictors of veterinary students' PD accuracy; however, our data did not support an association between arm length or proprioception and PD accuracy. Implementation of an exercise program aimed at improving grip strength in the veterinary curriculum is a novel approach to improve bovine TRP training, with possible additional benefits to general student well-being related to exercising.

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NOTES

a Breed'n Betsy, Brad Pickford, Australia, http://www.breednbetsy.com.au/
b Haptic Cow, Virtalis Ltd., Cheshire, UK, https://www.virtalis.com/haptic-cow/
c Takei Scientific Instruments Co., Ltd., Niigata City, Japan
d Model 770, Computer Sports Medicine, Inc., Stoughton, MA, USA
e Hitech Therapy CC, Bryanston, South Africa
f MINITAB Statistical Software, Release 13.32, Minitab Inc, State College, Pennsylvania, USA
g International Business Machines Corp., Armonk, NY, USA

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APPENDIX 1: 2016 PREGNANCY DIAGNOSIS CHALLENGE EXERCISE PROGRAM QUESTIONNAIRE

Date: _______________

Name: _________________

Student number: _________________

Gender: _____________

Did you enjoy the exercise program?

____

Which aspects did you not enjoy?

____

How could such a program be improved?

____

What benefits did you get out of the exercise program?

____

Do you think your muscle strength has improved through participation in the exercise program?

____

If yes, could you specify which aspect(s) (whole arm strength, endurance, grip strength, etc.)?

____

Do you feel a difference while performing rectal examinations after the exercise program?

____

If yes, please specify (less tired during rectal palpations, can do more rectal exams comfortably, etc.):

____

Do you think an exercise DVD/app would be useful and utilized by students?

____

Additional comments/suggestions:

____