Passive teaching is not as effective as active teaching for learning the standard technique of pivot shift test

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ABSTRACT
Objective Two major teaching methods available for learning the pivot shift test are active teaching with real-time feedback from an instructor and passive teaching through the use of instructional textbooks or videos. The purpose of this study was to determine the effect of active and passive teaching methods on the execution of the proper technique of the pivot shift test.

Methods Six orthopaedic surgery residents each performed 110 pivot shift tests on a fresh-frozen, cadaveric pelvis-to-toe specimen with anterior cruciate ligament insufficiency and lateral meniscectomy. Participants performed 10 repetitions before teaching and a total of 100 repetitions after either active or passive teaching. Six degree-of-freedom kinematics of the knee defined by the Groot/Sunray coordinate system were recorded after every fifth repetition using an electromagnetic tracking system. Anterior/posterior translation of the lateral knee compartment during the reduction event was also quantified. Depending on the normality of the data, a two-tailed t-test or Wilcoxon rank-sum test was used for comparisons of kinematics between the active and passive teaching groups and between successful and unsuccessful trials within each teaching group. Statistical significance was set at p<0.05.

Results The success rate after active teaching was 31.7% compared with 30.0% after passive teaching. However, the starting position of the reduction event in the active teaching group was rotated by more than twice the amount of valgus rotation compared with the passive group (7.4°±3.3° vs 3.0°±2.7°; p<0.001). During the reduction event, the active teaching group underwent 4.4°±5.6° of external rotation, which is 10.6° in the opposite direction of the passive group (6.2°±4.8° of internal rotation; p<0.001).

Conclusion Successful pivot shift tests can be performed after passive teaching, but the standard technique is not as effectively learnt through passive teaching since traditional external rotation during the reduction event was not used as in the active teaching group.

Level of evidence V.

INTRODUCTION
The pivot shift test is highly relevant to treatment decisions in patients with anterior cruciate ligament (ACL) insufficiency. Several studies have shown that the grade of the reduction event correlates with clinical outcome, patient satisfaction and development of osteoarthritis after an ACL injury. The pivot shift test is a complex, multiplanar manoeuvre, and as a result, it is dependent on the skills and experience of the examiner. Standardising the hand position and manoeuvres of the pivot shift test was shown to improve the consistency of the quantitative evaluation of rotatory knee laxity in a group of experienced senior orthopaedic surgeons. This suggests that how to teach the test is an important factor in having the ability to produce consistent results of the test across examiners.

The pivot shift is defined by two phases: anterior translation of the lateral tibial plateau and an accelerated posterior translation known as the reduction event. Internal rotation of the tibia is coupled with anterior translation of the lateral tibial plateau, while the reduction event entails posterior translation and external rotation of the lateral tibial plateau. The traditional pivot shift test is executed by maintaining internal rotation and valgus stress during knee flexion. In a flexion range of 25°–40°, the tibial subluxation is followed by a palpable reduction translation caused by the tension of the iliotibial tract. The rotatory knee laxity can be quantified using the magnitude of the generated translation of the lateral tibial plateau during the test.

Two major teaching methods available for learning the pivot shift test are active teaching with real-time feedback as seen in residency/fellowship training programmes and passive teaching through the use of instructional videos. While active teaching provides individualised feedback and more engaged learning, it is difficult to access this type of instruction as easily as passive teaching instructional videos. Thus, the purpose of this study was to determine the effect of active and passive teaching methods on the execution of the proper technique of the pivot shift test. This information will allow for the assessment of the effectiveness of passive teaching methods that are more readily available and that could take the place of active teaching.
was also quantified through this system using a method based on the anatomic landmarks such as Gerdy’s tubercle, fibular head, and lateral femoral epicondyle as previously defined. The accuracy of this system was validated by testing in our laboratory and was found to be 0.8 mm for translation and 0.7° for rotation.

During the testing protocol, each participant performed a total of 110 pivot shift tests on the prepared pelvis-to-toe specimen with six degree-of-freedom kinematics recorded during every fifth pivot shift test. Each participant performed their baseline technique for first 10 repetitions (kinematics recorded for two trials) before receiving either passive or active education to learn the pivot shift test. After an initial teaching session, each participant performed 50 repetitions of the pivot shift test (kinematics recorded for 10 trials), and then repeated the assigned teaching method before completing a final 50 repetitions (kinematics recorded for 10 trials). Passive teaching entailed watching a video that had demonstrations of the pivot shift test on different models (saw bone, cadaveric and human) in the following three steps: (1) hip abduction, axial compression and internal rotation; (2) valgus stress and gentle flexion; and (3) flexion and release of internal rotation to produce the reduction event. Active teaching involved initial critique from the investigator based on his or her observations of the participant’s baseline pivot shift technique with allowed time for questions. The kinematics in varus/valgus, internal/external rotation and flexion/extension were evaluated to determine difference between the active and passive teaching groups.

**Data analysis**

The starting position and motion of the reduction event were determined by analysing the slope of the plotted curve of the anterior/posterior translation of the lateral knee compartment versus time. On this plot, a sign inflection change from positive to negative indicates the initiation of the reduction event, and then a negative sign inflection change from negative to positive indicates the end of the reduction event (Figure 2). A successful pivot shift test was defined by three criteria: (1) a reduction event is present, which was determined by ensuring that there was a change in sign inflection of the slope of the plotted curve of the anterior/posterior translation of the lateral knee compartment versus time as described above, (2) the reduction event initiates below 70° knee flexion, and (3) the magnitude of the translation of the lateral knee compartment during the reduction event is above a minimum threshold of one SE below the average measured translation for each participant. Unsuccessful pivot shift tests were identified as one of the following: (1) an inflection change from positive to negative with a slope less than the acceptance threshold of one SE below the average measured translation for each participant, or (2) an inflection change from positive to negative followed by a positive inflection change from negative to positive. All pivot shift tests were video recorded to assess the subjective determination of the effect of any of the teaching methods on the ability to perform a successful pivot shift test.

**METHODS**

**Participants and data collection**

Institutional Review Board approval was obtained prior to the start of this study. Six orthopaedic surgery residents with no prior experience performing the pivot shift test were recruited to be the participants in this study. They were randomised to receive either the passive education (instructional video) or active education (one-on-one lesson) to learn the pivot shift test with a total of three participants in each of the teaching groups. A power analysis was completed prior to the start of the study to determine the number of subjects needed in the study. A cadaveric pelvis-to-toe specimen was frozen at −20°C prior to the testing protocol. The specimen was thawed for 36 hours at room temperature and then a thorough manual, radiographic and arthroscopic exam was conducted to ensure that the specimen did not have previous osteoarthritis or ligamentous abnormalities. The ACL and lateral meniscus were resected arthroscopically to enable a positive pivot shift test.

In order to track six degree-of-freedom kinematics of the knee, two electromagnetic tracking sensors were mounted onto the bones around the knee joint, one on femoral shaft and one on the tibia shaft (Figure 1). Six degree-of-freedom kinematics of the knee defined by the Grood/Suntay coordinate system were recorded using an electromagnetic tracking system (FASTRAK, Polhemus, Colchester, Vermont, USA) after every fifth repetition. The following bony landmarks were digitised with the leg in a static position using a third sensor mounted on a stylus: medial/lateral femoral epicondyle (at the insertion of the MCL and LCL, respectively), medial/lateral tibial plateau (at the joint line, along the collateral ligaments) and two landmarks along the shaft of tibia and femur (approximately 20 cm from the anterior aspect of the joint line). Eight of these points were used to generate the orthogonal joint coordinate system that could determine a six degree-of-freedom description of the tibia with respect to the femur. Translation of the lateral knee compartment was also quantified through this system using a method based on the anatomic landmarks such as Gerdy’s tubercle, fibular head, and lateral femoral epicondyle as previously defined. The accuracy of this system was validated by testing in our laboratory and was found to be 0.8 mm for translation and 0.7° for rotation.

**Figure 1** Experimental set-up to record six degree-of-freedom kinematics using an electromagnetic tracking system. Arrows=location of electromagnetic sensors placed on the tibia and fibula (connected to FASTRAK system by wires shown in picture). *Transmitter.

**Figure 2** Typical anterior/posterior translation of the lateral knee compartment during the pivot shift test. Initiation of the reduction event labelled as A: sign inflection: + to −; end of the reduction event labelled as B: sign inflection − to +.
were divided into two separate groups for the statistical analysis. The first group consisted of unsuccessful pivot shift tests without a reduction event, which meant that the pivot shift test did not meet criteria 1 or 2. The second group consisted of unsuccessful pivot shift tests with a reduction event, which meant that the pivot shift test met criteria 1 and 2 but not criteria 3.

Normality of the data was determined by using a Kolmogorov-Smirnov test. A two-tailed t-test or Wilcoxon rank-sum test was used depending on the normality of the data in order to determine the effect of active versus passive teaching method on the starting position and motion of the tibia during the reduction event in each degree-of-freedom. These measures were also compared in successful trials and unsuccessful trials with a reduction event within each teaching group. Additionally, a χ² test was used to evaluate the effect of repeating the assigned teaching method on the success rate of the pivot shift test. Statistical significance was set at p<0.05.

RESULTS
Success rate of pivot shift test
Six degree-of-freedom kinematics were recorded for 12 pivot shift tests prior to any teaching across all participants and none of them resulted in a successful pivot shift test. After teaching, six degree-of-freedom kinematics were recorded for a total of 120 pivot shift tests across all participants. Of these recorded kinematics, 37 pivot shift tests were successful by all three criteria across all participants. The overall success rate across all participants was 30.8% with the success rate in the active teaching group being 31.7% compared with 30.0% in the passive teaching group. Active teaching resulted in a total of 19 successful trials, 11 unsuccessful trials with a reduction event and 30 unsuccessful trials without a reduction event, while passive teaching resulted in a total of 18 successful trials, 11 unsuccessful trials with a reduction event and 31 unsuccessful trials without a reduction event. Only 26.8% of the unsuccessful trials after active teaching and 26.2% of unsuccessful trials after passive teaching had a reduction event. Eleven successful pivot shift tests were recorded after repeating the teaching method compared with 26 successful pivot shift tests performed before repeating the teaching method (p<0.005).

Differences in kinematics between active and passive teaching
The starting position and motion of the tibia during the reduction event of successful pivot shift tests by all three criteria were significantly different between the active and passive teaching groups in varus/valgus and internal/external rotation, respectively. The starting position of the reduction event in the active teaching group was in 147° more varus than the passive group (p<0.001 using a two-tailed t-test) (Table 1). In the passive teaching group, there was 54° more flexion (p<0.001 using a two-tailed t-test) and 55° more varus rotation (p<0.001 using a two-tailed t-test) during the reduction event in the successful trials compared with unsuccessful trials with a reduction event (Table 2).

DISCUSSION
Active teaching and passive teaching of the pivot shift test resulted in significantly different starting positions and motion during the reduction event of the pivot shift test. Active teaching resulted in the traditionally described technique of the pivot shift test with external rotation of the tibia occurring during the reduction event, while the passive teaching group had internal rotation during the reduction. A previous study has shown that during the reduction event of the pivot shift test, the external rotation was 13°±8°. Though the amount of external rotation for the active teaching group in this study was lower than that previously reported, the same direction of the rotation suggests that the technique of the test was correct in the active teaching group and incorrect in the passive teaching group.

The passive teaching group also had significantly different starting position and motion during the reduction event between successful trials and unsuccessful trials with a reduction event, while the active teaching group did not. The difference between teaching group started the reduction event in 5° more valgus than the unsuccessful trials with a reduction event, which actually started in varus (p<0.001 using a two-tailed t-test) (Table 1). In the passive teaching group, there was 54% more flexion (p<0.001 using a two-tailed t-test) and 55% more varus rotation (p<0.001 using a two-tailed t-test) during the reduction event in the successful trials compared with the unsuccessful trials with a reduction event (Table 2).

Comparison of successful trials and unsuccessful trials with a reduction event
In the active teaching group, the starting position and motion of the tibia was no different in internal/external rotation, flexion and valgus/varus rotation during the reduction event between the successful trials and unsuccessful trials with a reduction event (Table 1 and 2). Successful trials in the passive

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Starting position of the reduction event in each degree-of-freedom for successful pivot shift tests and unsuccessful pivot shift tests with a reduction event within each teaching group (average±SD)</th>
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<td><strong>Active teaching method</strong></td>
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<td></td>
<td><strong>Successful</strong></td>
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<td></td>
<td><strong>Successful</strong></td>
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<tr>
<td>Varus (−)/valgus (+) rotation</td>
<td>7.4°±3.3°**</td>
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<tr>
<td>Flexion</td>
<td>42.7°±9.7° *</td>
</tr>
<tr>
<td>Internal (+)/external (−) rotation</td>
<td>0.3°±13.8°</td>
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*Statistically significant difference with p<0.001 between successful pivot shift tests after active and passive teaching.
†Statistically significant difference with p<0.001 between successful pivot shift tests and unsuccessful pivot shift tests with a reduction event within teaching group.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Motion during the reduction event in each degree-of-freedom for successful pivot shift tests and unsuccessful pivot shift tests with a reduction event within each teaching group (average±SD)</th>
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<td><strong>Active teaching method</strong></td>
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<td></td>
<td><strong>Successful</strong></td>
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<tr>
<td>Varus (−)/valgus (+) rotation</td>
<td>−10.7°±4.0°</td>
</tr>
<tr>
<td>Flexion</td>
<td>27.6°±6.5°</td>
</tr>
<tr>
<td>Internal (+)/external (−) rotation</td>
<td>−4.4°±5.6°†</td>
</tr>
</tbody>
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*Statistically significant difference with p<0.001 between successful pivot shift tests after active and passive teaching.
†Statistically significant difference with p<0.001 between successful pivot shift tests after active and passive teaching.
successful and unsuccessful trials with a reduction event in the passive shift position group were a result of incorrect technique of pivot shift test with not enough valgus at the start of the reduction event. This finding along with the significantly decreased valgus starting position of the successful passive teaching trials compared with the active teaching trials suggests that the application of a valgus load is not communicated sufficiently by the passive teaching method despite being included as part of the three major steps of the pivot shift test explained in the instructional video. Future studies could evaluate teaching of a valgus starting position further in order to improve passive teaching by assessing the amount of valgus load that is applied after different cues that emphasize this point in passive teaching methods.

While this is the first study that evaluates the effect of teaching methods on the learning of the pivot shift test, the effect of active and passive teaching methods on the learning of the general musculoskeletal exam has been examined previously. It was determined that knowledge of the musculoskeletal exam was no different after written/video instruction and individual teaching as assessed by a written exam. However, the active teaching group in that study was superior at actually performing the physical exam based on evaluations by trained standardised patients. The results from this previous study are consistent with the findings of this study and suggest that there is a component of hands-on learning that contributes to the ability to perform the pivot shift test properly.

Currently, no models or tools are available to facilitate the learning or assessment of the pivot shift test. It has been shown that there is a significant role for standardised tools in the teaching of physical exam skills. The use of standardised physical examination teaching models under the instruction of a non-physician is equivalent to teaching the general physical exam as instruction given by the physician with practice on peers. Development of a lower extremity model that would be able to assess the performance of the pivot shift test based on recorded kinematics during its performance would be able to provide individualised feedback equivalent to that of active teaching. Such a model would also allow for practice of individual component of the exam if there was a particular motion that an examiner was performing incorrectly. Development of this tool and others to facilitate the teaching of the pivot shift test could resolve the difficulty with accessibility since a physician would not be needed to teach the test effectively.

Another finding of this study is that there was a statistically significant decline in the number of successful pivot shifts after the second teaching session compared with the first. This was an unexpected finding and suggests that even though additional learning takes place after the second teaching session, the factor of fatigue might have played a role in the inability to perform successful pivot shift tests. This is important consideration for the design of learning courses or module for the pivot shift test since there might be a threshold for the number of consecutive pivot shift tests that can be done without the influence of fatigue. This is also a consideration for the design of future studies that evaluate the effects of teaching method.

One of the limitations of this study is that while each participant performed a total of 100 pivot shift tests after teaching to allow for enough repetitions for learning, the six degree-of-freedom kinematics were only recorded every fifth pivot shift test performed. This makes it difficult to assess the actual effect of repetition on learning of the proper technique since there could be successful pivot shifts performed that were not recorded. Additionally, another limitation of the experimental design is that only one specimen was used for the whole testing protocol. While there was some increased knee rotatory laxity noted towards the end of the testing protocol, the criteria for determination of a positive pivot shift test accounted for the average anterior/posterior translation of the lateral knee compartment for each subject. Thus, changes in rotatory laxity of the knee were normalised when considering which pivot shift tests are positive.

CONCLUSION

Since the pivot shift test is a complex and multiplanar manoeuvre, it can be challenging to teach. In this study, the effects of passive and active teaching methods on the pivot shift technique were assessed in order to see if passive teaching methods could be used in the place of active teaching methods since those are more easily accessible. Based on the findings of this study, the pivot shift test can be successfully performed with passive teaching, but the standard technique is not effectively learnt through passive teaching, and thus it cannot be the sole teaching method used to develop the proper technique. Future studies can look at the characteristics of active teaching that correlate with learning of the proper technique and translate these characteristics to the passive teaching method and integrate them into models/tools to provide an effective teaching method that can be readily accessed.

Contributors NKP was responsible for data analysis and manuscript preparation. CIM, KN, SC, EH and JH-NW were responsible for modification of the study design and data collection, processing and analysis. RED and VM were the primary investigators on this project and were responsible for formulation of the study design as well as review and final approval of the manuscript.

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Competing interests VM and RED have a conflict of interest due to a technology they licenced to Impellia through the University of Pittsburgh that can quantify the pivot shift test.

Patient consent Not required.

Ethics approval Approval was obtained from the University of Pittsburgh IRB prior to the start of this study.

Provenance and peer review Not commissioned; externally peer reviewed.

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REFERENCES