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Accuracy of Medial Tibiofemoral Joint Space Palpation Among Second-Year Doctor of Physical Therapy Students Using Ultrasound Verification: An Observational Study

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ABSTRACT

Background: Palpation skills are universally taught in physical therapy education programs worldwide. Accurate palpation is necessary for diagnosis and to guide interventional approaches. The primary purpose of this investigation was to measure ultrasonographic-confirmed palpation accuracy of the medial tibiofemoral joint space among second-year Doctor of Physical Therapy students examining participants with characteristics representative of patients seen in clinical practice.

Methods: Five second-year Doctor of Physical Therapy students served as examiners. Thirty-six participants contributed 67 knees for examination. The primary outcome was ultrasonographic-confirmed palpation accuracy, and the secondary outcomes evaluated the association between palpation accuracy and participant characteristics.

Results: Pooled examiner accuracy was 39%. Chi-Square analyses revealed no association between pooled examiner palpation accuracy and BMI category (x^2=1.46, p=0.48), age category (x^2=0.21, p=0.65), sex (x^2=1.47, p=0.23), skin tone (x^2=0.06, p=0.81), or side of the examined knee (x^2=0.27, p=0.61). Individual examiner palpation accuracy ranged from 14% to 75%, revealing a significant difference across examiners (x^2=15.0, p=0.005). Two examiners had a combined accuracy of 64%, while the remaining 3 had a combined accuracy of 24%. Chi-Square analyses revealed no association between "successful" vs "unsuccessful" examiners and BMI category (x^2=3.54, p=0.17), age category (x^2=1.39, p=0.24), sex (x^2=4.22, p=0.04), skin tone (x^2=0.001, p=0.97), or side of the examined knee (x^2=0.08, p=0.77).

Conclusion: This investigation provides original data of ultrasonographic-confirmed palpation accuracy among second-year Doctor of Physical Therapy students examining participants with characteristics representative of patients seen in clinical practice. Results may help inform instructional approaches and curricular design in physical therapy education.

Keywords: Ultrasound imaging; Palpation; Tibiofemoral joint; Orthopedic examination; Physical therapy education.

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INTRODUCTION

Knee pain is a common complaint among patients seeking orthopedic physical therapy care. An estimated 650 million people worldwide over 40 years old have some form of knee osteoarthritis, most commonly affecting the structures of the medial joint compartment [1]. Structures that are commonly injured in the knee, particularly in the medial joint compartment, including the fibrocartilaginous menisci, account for up to 20% of orthopedic surgeries in the United States [2]. Physical therapy examination of patients with orthopedic complaints often includes palpation, which evaluates the temperature, texture, tension, mobility, and pain response in various bony and soft tissue structures [3, 4]. In patients reporting knee region pain, palpation is often used to evaluate the tibiofemoral joint (TFJ) space, ligaments, and the peripheral portion of the menisci [3, 4]. Accurate palpation is necessary to provide meaningful information about a patient's diagnosis and guide interventional approaches like soft tissue and joint mobilization/manipulation techniques. Unfortunately, published studies evaluating palpation have consistently found generally poor accuracy (which can be defined as <50% to use a generously low standard of accuracy) for a variety of neuromusculoskeletal structures in the extremities and spine regardless of examiner specialty or experience [5-12]. The reason for poor palpation accuracy among novice and experienced examiners remains unclear, although it can be reasonably attributed to the depth and complexity of the target bony and soft tissue structures and similarities in shape and texture of regional anatomic structures resulting in false positive findings.

Palpation skills are universally taught in physical therapy education programs worldwide. Most often, the 'gold standard' for gauging a student's success in palpating a structure is the judgment of the supervising faculty member or laboratory assistant, which is problematic given that palpation accuracy is poor even among experienced examiners [7, 9]. Alternatively, ultrasound imaging (USI) has recently been shown to be a valuable tool for providing confirmation and feedback about palpation accuracy in a variety of neuromusculoskeletal structures. In addition, it has been used as a training aid to improve the palpation skills of students and residents in graduate medical education [13-18]. As a safe, low-cost, and portable point-of-care imaging modality, USI is ideally suited to provide real-time evaluation of many superficial structures in the neuromusculoskeletal system, which provides opportunities for training and feedback for students developing orthopedic examination skills [19].

Only one published study has investigated USI-confirmed palpation accuracy among physical therapy students[6]. However, several studies have used USI to evaluate palpation accuracy in a variety of neuromusculoskeletal structures among students and residents in graduate medical education [5,8, 10-12]. Additionally, with few exceptions, palpation accuracy studies utilize 1 or 2 models with normal or low body mass index (BMI), which does not represent patients seen in clinical practice (average BMI in the United States is 26.5 kg/m^2) [20]. Despite using models with ideal anthropometric characteristics, students and residents have demonstrated generally poor palpation accuracy regardless of the program year [5-8, 10-12]. Gaudreault et al. [6], investigating USI-confirmed tendon and joint space palpation accuracy in the upper and lower extremities among 22 first-year Master of Physiotherapy students, found low success rates across all structures (ranging from 9% to 64%), including 31% accuracy for the medial TFJ space. Examiners palpated two female models with BMI values of 21.3 and 21.5 kg/m^2, respectively. Similarly, Huang et al. [8], investigating USI-confirmed tendon and joint space palpation accuracy in the upper and lower extremities among 37 physician residents, found low success rates across all structures (ranging from 8% to 62%), including 38% accuracy for the medial TFJ space. Examiners palpated two male models with 21.6 and 21.3 kg/m^2 BMI values, respectively. Mehta et al.,[10] investigating USI-confirmed tendon and joint space palpation accuracy in the lower extremity among 18 physiatry residents, found low success rates across all structures (ranging from 14% to 36%), including 14% accuracy for the medial TFJ space with little difference noted based on year of post-graduate training. Examiners palpated 1 male and 1 female model with 25 and 23 kg/m^2 BMI values, respectively.

Based on a review of the literature, there is a need to evaluate USI-confirmed palpation accuracy among physical therapy students to identify gaps in training and education and to inform the development of strategies for improving orthopedic examination skills in physical therapy education [18]. Additionally, very few palpation studies include models with anthropometric characteristics representative of the general population, making the results less generalizable. Therefore, the primary purpose of this investigation was to measure USI-confirmed palpation accuracy of the medial TFJ space among five second-year Doctor of Physical Therapy students examining a convenience sample of participants with BMI values representative of patients seen in clinical practice. We hypothesized that pooled examiner palpation accuracy would be poor and palpation accuracy would be negatively associated with participant BMI.

METHODS

This cross-sectional observational study investigated the ability of second-year Doctor of Physical Therapy students to locate the medial TFJ space in a convenience sample of asymptomatic volunteers. Study and recruitment procedures for this investigation involving human subjects were approved by the Institutional Review Board at Winston-Salem State University (IRB-FY2023-3). Participants were recruited from among students, faculty, and affiliates of the Department of Physical Therapy at Winston-Salem State University, distinguished as the only Historically Black College and University (HBCU) with graduate physical therapy education in North Carolina.

Examiners

Five second-year Doctor of Physical Therapy students agreed to participate as examiners in this study while participating as co-investigators in a faculty-led research project, a requirement to complete their degree successfully. Before study participation, student examiners completed all required didactic and clinical coursework, including gross anatomy, basic skills, a year-long orthopedic physical therapy course series, and an 8-week outpatient clinical rotation.

Student examiners received approximately 10 hours of supervised training from their research advisor (NJS), who is Registered in Musculoskeletal® sonography by the Alliance for Physician Certification & Advancement and has over six years of experience performing and teaching diagnostic USI. Training consisted of instructor scanning demonstrations, onboard scan-along modules (Sonosite PX system), and supervised scanning of the medial knee region, including identification of the medial collateral ligament, medial meniscus, and bony features of the TFJ space.

Participants

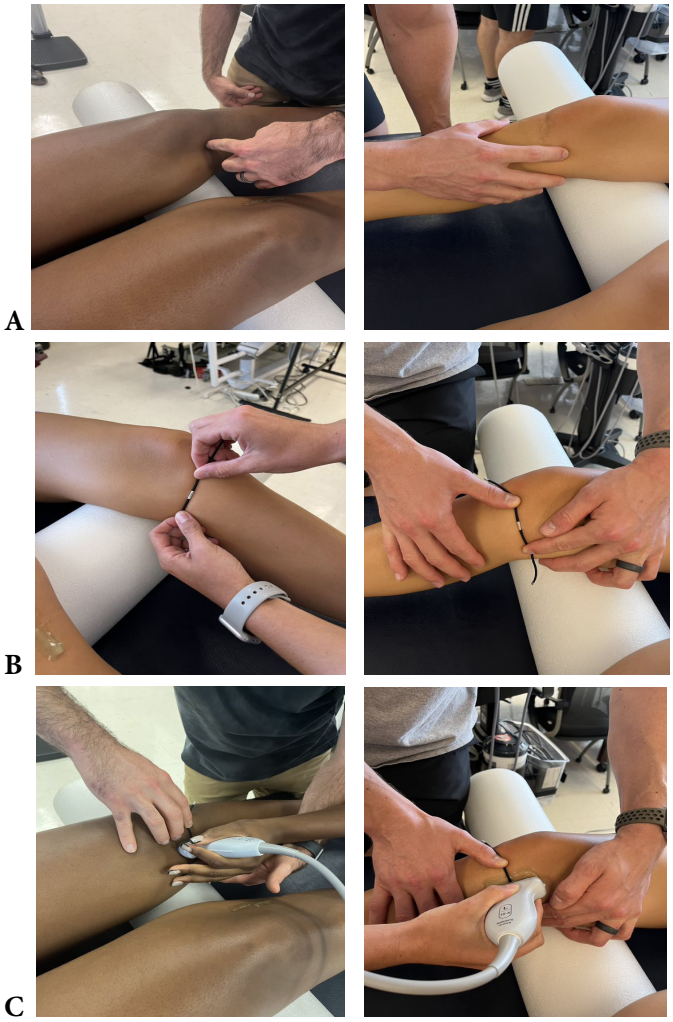
A convenience sample of asymptomatic adult volunteers was recruited for participation. Study eligibility was determined by the parent investigation, a study evaluating medial meniscal extrusion using USI, and included participants with at least one eligible knee who were either 18 to 30 years old or 50 to 75 years old. Eligible participants had to be able to follow basic verbal commands, lie on their backs, and stand without assistance. Individuals were excluded from the study if they reported an intra-articular knee trauma or surgery in both knees, an invasive procedure in both knees in the prior 6 months, or an intra-articular injection in both knees in the prior month.

Study Procedures and Instrumentation

Upon arrival for data collection, participants provided written informed consent and completed a short questionnaire including a brief knee-specific health history and basic demographic information. Participants were asked to remove their shoes and socks, and their height and weight were measured using a calibrated digital scale. Height and weigher were used to calculate and categorize each participant's BMI as either: underweight (<18.5 kg/m^2), healthy weight (18.5 to <25 kg/m^2), overweight (25 to <30 kg/m^2), or obese (≥30 kg/m^2). Participants were then asked to stand with their feet about 12 inches apart, and 2 examiners evaluated their frontal and sagittal plane knee postures. Finally, participants were asked to lie on their backs with their heels resting on a 6-inch foam roll, and 2 examiners evaluated their sagittal plane knee posture. Examiners agreed on observed knee postures and recorded a single value.

Palpation and USI procedures were performed with participants in supine and a 6-inch foam roll placed under their knees creating approximately 30° flexion. Participants were instructed to relax their hips, resulting in slight external rotation making the medial knee region more accessible. Next, examiner 1 palpated the medial TFJ space. Once examiner 1 finalized their palpation location, an assistant placed a 1/8-inch (3 mm) opaque marker under the palpating finger to preserve the desired location. The unique procedures for marking and recording palpation location were chosen for this investigation to avoid examiners removing their finger from their desired location and providing a marker (and resulting hypoechoic shadow) approximating the size of a typical fingertip. Once examiner was satisfied with the placement of the opaque marker, examiner 2 placed a 15-4 MHz linear-array transducer (Sonosite PX; FUJIFILM Sonosite, Kennewick, WA) in short axis and centered over the opaque marker capturing a still image (FIGURE 1). By convention, the transducer was oriented so that the left side of a captured image represents proximal. All USI procedures were overseen by the research advisor and principal investigator (NJS) to ensure quality and fidelity.

Figure 1: Palpation and image acquisition procedures: (**A**) localization of suspected medial tibiofemoral joint space, (**B**) placement of opaque marker, and (**C**) placement of ultrasound transducer over opaque marker for image acquisition.



Captured images were labeled and saved in a password-protected file under a participant-specific study ID. Images were exported as anonymized JPEG files using a USB drive and stored on a password-protected computer. Before data collection, the authors determined that incidental USI findings would be discussed with participants and, if

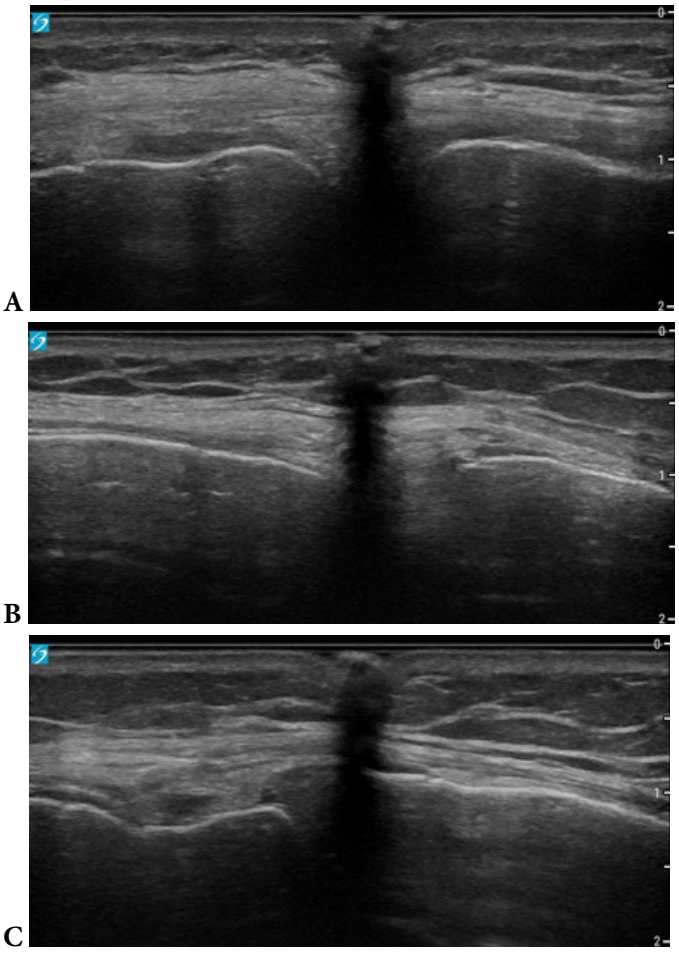
deemed necessary, a referral made to their primary care provider for further evaluation.

Image Review and Outcomes

The primary outcome of this investigation is pooled examiner palpation accuracy of the medial TFJ space. Palpation accuracy was determined by visual inspection of the hypoechoic shadowing generated by the opaque marker relative to the TFJ space. In addition, captured images were inspected and categorized by the principal investigator (NJS).

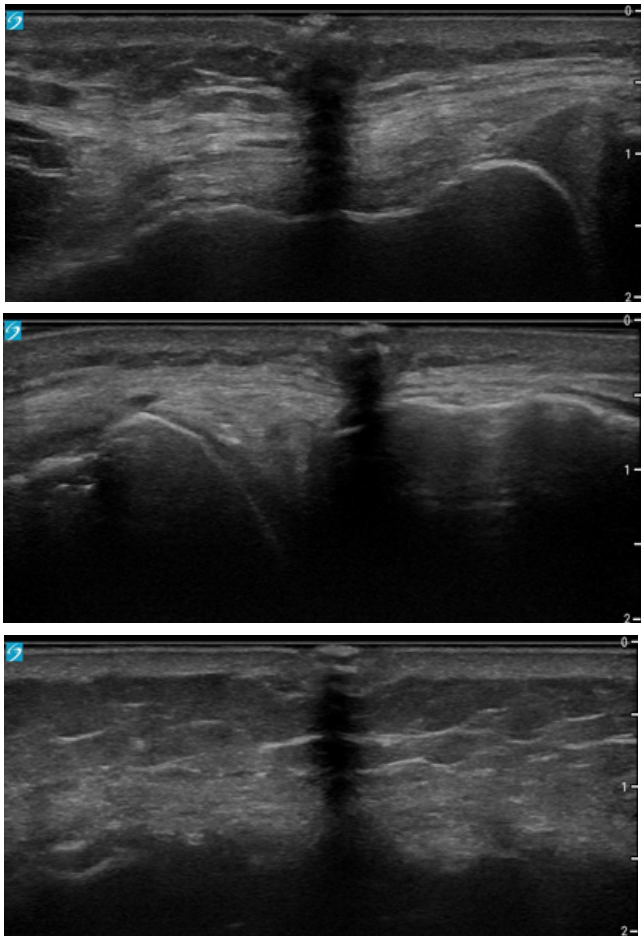
"Successful" palpation was defined as hypoechoic shadowing obscuring any aspect of the medial TFJ space, including the most distal aspect of the femoral condyle (as bone slopes into joint space) or the most proximal aspect of the tibial condyle (as bone slopes into joint space). The directional bias of successful palpation was labeled as "center" joint space (no bone obscured), "proximal" joint space (a distal aspect of sloping femoral condyle obscured), or "distal" joint space (a proximal aspect of sloping tibial condyle obscured) (FIGURE 2).

Figure 2: The directional bias of *successful* medial tibiofemoral joint space palpation: (**A**) center, (**B**) proximal/femoral side, and (**C**) distal/tibial side.



Alternatively, "failed" palpation was defined as hypoechoic shadowing clearly outside of the medial TFJ space. The directional bias of a failed palpation was labeled as "proximal" (region of femoral condyle), "distal" (region of tibial condyle), or "unknown" (no identifiable landmarks to localize palpation) (FIGURE 3).

Figure 3. The directional bias of *failed* medial tibiofemoral joint space palpation: (**A**) proximal on the femoral condyle, (**B**) distal on the tibial condyle, and (**C**) unknown lacking bony landmarks.



Statistical Analysis

Descriptive statistics were used to summarize and categorize participant characteristics. Palpation accuracy of the medial TFJ space was calculated for individual examiners and by pooling results from all examiners. Chi-Square analyses were used to investigate associations between examiner palpation accuracy and participant characteristics, including BMI category, age category, sex, skin tone, and side of the examined knee.

RESULTS

Examiners

Characteristics of the student examiners are presented in TABLE 1. Data from 5 examiners and 67 knees were analyzed. The number of knees palpated by each examiner ranged from 12 (18%) to 14 (21%), and the number of knees that each examiner performed USI ranged from 11 (16%) to 17 (25%).

Table 1: Characteristics of student examiners.

	Student 1	Student 2	Student 3	Student 4	Student 5
Age (years)	28.4	25.9	24.8	28.5	33.4
Sex	Male	Female	Female	Male	Male
Hand Dominance	Right	Left	Right	Right	Right
Knees Examined	12	14	14	13	14
Ultrasound Exams	12	15	11	12	17

Participants

Characteristics of the study participants are presented in TABLE 2. Data from 36 participants contributing 67 knees were analyzed. The average BMI was 27.4±5.9 kg/m^{2,} with 13 participants contributing 25 knees (37%) from the healthy weight category, 13 participants contributing 24 knees (36%) from the overweight category, and 10 participants contributing 18 knees (27%) from the obese category. No participants fell into the underweight category. The average age was 36.0±16.4 years old, with 25 participants contributing 46 knees (69%) from the ≤30-year-old category and 11 participants contributing 21 knees (31%) from the ≥50-year-old category. Considering race/ethnicity, 15 participants contributed 28 knees (42%) that identified as black or bi/multiracial, and 20 participants contributed 37 knees (55%) identifying as white, providing examiners with a variety of skin tones.

Table 2: Characteristics of study participants and knees examined.

	Participants (n=36)	Knees Examined (n=67)
Average age (years)	36.0 ± 16.4	---
≤30-year-old category	25.7 ± 2.3	46 (69%)
≥50-year-old category	59.5 ± 7.2	21 (31%)
Average BMI (kg/m^2)	27.4 ± 5.9	---
Healthy weight category	13 (36%)	25 (37%)
Overweight category	13 (36%)	24 (36%)
Obese category	10 (28%)	18 (27%)
Sex		
Female	19 (53%)	35 (52%)
Male	17 (47%)	32 (48%)
Race/Ethnicity		
Black	13 (36%)	24 (36%)
White	20 (56%)	37 (55%)
Bi/multiracial	2 (6%)	4 (6%)
No indicated	1 (3%)	2 (3%)
Skin Tone		
Dark	14 (39%)	27 (40%)
Light	22 (61%)	40 (60%)

**Data presented as:* Mean ± SD *or* Count (%)

BMI=body mass index; kg/m^2=kilograms per meters squared

Considering knee-related medical history, 3 participants reported prior trauma/surgery in 1 of their knees (contributing to the other knee for data collection), and 1 participant reported diagnosis of knee arthritis in both knees contributed (3%). No participants reported having a recent injection procedure in either knee. Considering standing knee posture, 3 participants contributing 4 knees (6%) were classified with genu varum, 5 participants contributing 6 knees (11%) were classified with genu recurvatum, and 1 participant contributing 2 knees (4%) was classified with knee flexion contracture. The remaining knees were classified as normal/neutral postures. Considering supine knee posture, 11 participants contributing 15 knees (22%) were classified with genu recurvatum, and 1 participant contributing 2 knees (3%) was classified with knee flexion contracture. The remaining knees were classified as normal/neutral postures.

Palpation Accuracy

The number and percentage of successful and failed palpations of the medial TFJ space, including directional biases, were calculated for all examiners (TABLE 3). *Pooled* examiner accuracy for palpating the medial TFJ space was 39% (26 of 67 knees). Considering directional bias for *successful* palpations, 13 knees (50%) were "center" joint space, 9 knees (35%) were "distal" joint space, and 4 knees (15%) were "proximal" joint space. Considering directional bias for *failed* palpations, 29 knees (71%) were missed "proximal", 2 knees (5%) were missed "distal", and 10 knees (24%) were "unknown" based on lack of bony landmarks to localize. Among the 31 participants contributing both knees for examination, the medial TFJ space was successfully palpated in *both knees* 23% of the time, in a *single knee* 29% of the time, and not located in either knee 48% of the time. Chi-Square analyses (TABLE 4) revealed no association between *pooled* examiner palpation accuracy and any participant characteristics, including BMI category (χ^2=1.46, p=0.48), age category (χ^2=0.21, p=0.65), sex (χ^2=1.47, p=0.23), skin tone (χ^2=0.06, p=0.81), or side of examined knee (χ^2=0.27, p=0.61).

Table 3: Examiner palpation accuracy and directional bias.

	All Examiners	Student 1	Student 2	Student 3	Student 4	Student 5
Successful Palpation	**26 (39%)**	**9 (75%)**	**6 (43%)**	**2 (14%)**	**7 (54%)**	**2 (14%)**
Center	13 (50%)	4 (44%)	1 (17%)	2 (100%)	5 (71%)	1 (50%)
Proximal/femoral side	4 (15%)	1 (11%)	2 (33%)	0 (0%)	0 (0%)	1 (50%)
Distal/tibial side	9 (35%)	4 (44%)	3 (50%)	0 (0%)	2 (29%)	0 (0%)
Failed Palpation	**41 (61%)**	**3 (25%)**	**8 (57%)**	**12 (86%)**	**6 (46%)**	**12 (86%)**
Proximal/femoral condyle	29 (71%)	1 (33%)	6 (75%)	10 (83%)	2 (33%)	10 (83%)
Distal/tibial condyle	2 (5%)	1 (33%)	0 (0%)	0 (0%)	1 (17%)	0 (0%)
Unknown	10 (24%)	1 (33%)	2 (25%)	2 (17%)	3 (50%)	2 (17%)

Table 4: Chi-Square analysis of the association between examiner and participant characteristics and palpation accuracy.

	x^2 value	df	p-value
Palpation Accuracy vs. ***Individual* Examiners**	15.0	4	*.005*
***Pooled* Examiner Palpation Accuracy** vs			
BMI Category	1.46	2	.481
Age Category	.211	1	.646
Sex	1.47	1	.225
Skin Tone	.060	1	.807
Side of Examined Knee	.268	1	.605
"Successful" Examiner Palpation Accuracy vs			
BMI Category	3.54	2	.170
Age Category	1.39	1	.239
Sex	4.22	1	.040
Skin Tone	.001	1	.969
Side of Examined Knee	.083	1	.774

χ2=Chi-Square; df=degrees of freedom; BMI=body mass index

Individual examiner palpation accuracy of the medial TFJ space ranged from 14% (2 of 14 knees) to 75% (9 of 12

knees), revealing a significant difference across examiners (χ^2=15.0, p=0.005). Two examiners successfully palpated the medial TFJ space more than half the time with a combined accuracy of 64% (16 of 25 knees) while the remaining 3 examiners had a combined accuracy of 24% (10 of 42 knees). Additional Chi-Square analyses revealed no association between "successful" vs "unsuccessful" examiners and any participant characteristics, including BMI category (χ^2=3.54, p=0.17), age category (χ^2=1.39, p=0.24), sex (χ^2=4.22, p=0.04), skin tone (χ^2=0.001, p=0.97), or side of the examined knee (χ^2=0.08, p=0.77).

DISCUSSION

This investigation describes the results of USI-confirmed palpation accuracy of the medial TFJ space among 5 second-year Doctor of Physical Therapy students examining participants with characteristics representative of patients seen in clinical practice. We found pooled examiner palpation accuracy of 39%, with individual examiner accuracy ranging from 14% to 75%. Our findings matched or exceeded those reported in recent studies investigating palpation accuracy of the medial TFJ space among physician residents and first-year Master of Physiotherapy students [6, 8, 10]. Consistent with prior studies, we found failed palpation of the medial TFJ space occurred predominantly in the proximal direction over the femoral condyle, accounting for 71% of misses in our investigation and ranging from 74% to 80% of missies among physician residents and first-year Master of Physiotherapy students [6, 8, 10]. In contrast to prior investigations, our participants provided a diverse and representative sample of BMI, age, sex, and skin tones for our examiners, including 67 knees from 36 participants with BMI values ranging from 18.8 to 47.2 kg/m^2.

Contrary to our original hypothesis, we found no association between examiner palpation accuracy and BMI. This finding held even when comparing our study's "successful" and "unsuccessful" examiners. While this investigation revealed generally low pooled examiner palpation accuracy of the medial TFJ space among second-year Doctor of Physical Therapy students, the findings are encouraging given the increased anthropometric complexity of our participants, which arguably increased the difficulty of successful palpation for our examiners. Additionally, despite the unique characteristics of our participants (not the least of which was higher BMI values, larger age ranges, and a variety of skin tones), our student examiners demonstrated palpation accuracy values matching or exceeding those published among physician residents [8, 10].

Data from this study can be used to inform teaching methods and curricular design in physical therapy education. Given the generally poor accuracy of palpation among students and clinicians across various disciplines regardless of experience, these data provide further evidence that innovative approaches are necessary to improve the clinical examination skills of students and clinicians that treat patients presenting with neuromusculoskeletal problems. Among the innovative approaches for improving examination skills among graduate medical education students is USI-assisted feedback. Kitagawa et al. [18], in a randomized trial comparing 3 sessions of USI-assisted versus traditional instruction in shoulder palpation among first-year physical therapy students, found improved scores for the USI group at all time points but lacked sufficient statistical power to find differences between groups. Bowers et al. [14], investigating a year-long USI training program with 8 didactic and 6 joint scanning sessions, found significantly improved lateral TFJ space palpation accuracy among 17 physiatry residents regardless of post-graduate year. Bitterman et al. [13], investigating an 18-week training program integrating USI and palpation skills in the upper extremity, found significantly improved palpation skills among 8 physiatry residents for bony prominences, joint spaces, and tendons. de Vries et al. [16], in a randomized trial investigating a single session of USI training versus traditional instruction on examiner confidence and accuracy in shoulder palpation, found significant improvements in the USI group among 64 osteopathic residents. Finally, Woods et al. [17], investigating a single session of USI training on palpating the long-head biceps tendon, found significantly improved accuracy among 10 physiatry residents regardless of post-graduate year.

Limitations

We recognize some potential limitations of our study. First, images were reviewed by a single examiner. While this could limit the validity of our findings, prior studies have demonstrated substantial to perfect inter-rater reliability, and our results are consistent with previously published studies investigating palpation accuracy of the medial TFJ space [6, 8]. Second, the student examiners in this investigation were not experienced in USI. While examiner inexperience could limit the validity of our results, it should be noted that the USI procedures used in this investigation were not difficult to perform, all examiners received adequate training before data collection, and all USI procedures were overseen by an experienced examiner (NJS) to ensure quality and fidelity. Finally, this investigation's student examiners may not represent most second-year Doctor of Physical Therapy students.

CONCLUSION

This investigation provides original data on USI-confirmed palpation skills among second-year Doctor of Physical Therapy students examining participants with characteristics representative of patients seen in clinical practice. This is the first study to describe Doctor of Physical Therapy students' competency in locating the medial TFJ space. While examiner palpation accuracy was generally low in this investigation, our results matched or exceeded those from previous studies utilizing physician residents and Master of Physiotherapy students with a nearly identical directional bias for failed palpations. These results may help inform instructional approaches and curricular design in physical therapy education. While encouraging

results have been reported utilizing USI as an adjunctive tool for improving clinical examination skills of students and residents in graduate medical education, further research is needed to determine the value of including USI-assisted training in physical therapy education, including the appropriate dose and timing within the curriculum.

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